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Mr S. G. Bass was my uncle.
he died in [illegible]

C. T. M.

View, showing the progress of the Works of the LONDON AND BIRMINGHAM RAILWAY,
near the Hampstead Road, in the year 1836.

G. F. Masterman.

A GLOSSARY

OF

CIVIL ENGINEERING,

COMPRISING THE

THEORY AND MODERN PRACTICE;

WITH THE

SUBJECTS OF FIELD AND OFFICE WORK, MECHANICAL ENGINEERING, ETC.

BY

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AUTHOR OF "RAILWAY PRACTICE."

WITH NUMEROUS WOODCUT ILLUSTRATIONS.

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PREFACE.

THE science of Civil Engineering may be considered the most prevailing topic of the day, and one of immense interest and importance; notwithstanding, there is no elementary work published in this country upon the subject, which induced the Author to produce this slight attempt, and he claims no merit or consideration beyond that of having compiled and arranged in an useful form what may be styled an introduction to that study.

He has illustrated the subject by numerous references to the various Public Works throughout the kingdom, and he has also availed himself of all that

had been previously written on the subject, with due respect to the most satisfactory authorities. There are likewise many rules inserted, which, although well known to the experienced, had not before appeared in a modified state; they are thus embodied in a popular style, for the use of the Student and the Amateur.

12, South Square, Gray's Inn,
May 20*th*, 1840.

ERRATA.

Page 30, line 23, *for* backs, *read* bricks.
— 40, — 10, — 250 feet span, *read* 25 feet span.
— 43, — 25, — something, *read* any thing.
— 47, — 14, — coffer dams, *read* coffer dams, or coffre dams.
— 49, — 2, — boats, hooks, *read* boat-hooks.
— 73, — 34, — water, *read* dam.
— 76, — 8, — material, *read* load.
— 76, — 26, — strains, *read* weights.
— 85, — 25, — straiths, *read* staiths.
— 89, — 18, — prismoidal, *read* prismoid.
— 100, — 29, — covered, *read* curved.
— 101, — 10, — posts, *read* parts.
— 105, — 11, — sheep, *read* sheet.
— 105, — 32, — C, *read* D.
— 105, — 32, — D, *read* C.
— 106, — 2, — lower, *read* upper.
— 106, — 3, — upper, *read* lower.
— 106, — 5, — D, *read* C.
— 107, — 21, — roading, *read* roadway.
— 109, — 7, — runs, *read* run.
— 109, — 21, — 33, *read* 33*.
— 129, — 9, — clumps, *read* clamps.
— 166, — 34, — crumped, *read* cramped.
— 171, — 27, — brick, *read* bridge.
— 182, — 29, — pig-iron, *read* iron.
— 224, — 19, — dry, *read* dug.
— 242, — 29, — P, *read* I. P.
— 269, — 25, — bone, *read* horn.
— 290, — 15, — mometum, *read* momentum.

GLOSSARY OF Civil Engineering

ABBREVOIR, or ABBREUVOIR (in masonry), the interstice or joint between two stones of an arch, and which is usually filled up with fine mortar, or cement.

ABUTMENT, a term much used in reference to any fixed points, from whence, or by which, any support or force is obtained; thus the extremities of a segmental arch are said to be supported on *abutments*, upon which it rests, or abuts: the extremities of a bridge are also termed *abutments*.

ACRE, a measure of land amounting to four square roods, or 160 square poles or perches; or 10 square chains: 4,840 square yards also form one acre.

ADHESION, the force acting on the surface of two separate bodies in contact with each other, which tends to bind them together, and which is proportionate to the number of touching

points. There are two kinds of adhesion: first, the natural attraction existing between the surfaces of unconnected bodies, and which is said to be greater with two bodies of a similar nature than with two of a different kind, as the force which prevents the wheels of a locomotive engine from slipping on a road or railway—(The adhesion of the wheels of the best modern locomotive engines to the rails, exclusive of the power to drive the engine itself, is supposed to be capable of overcoming a resistance equal to $\frac{1}{15}$th part of the insistent weight of the engine upon a level plane, or $\frac{1}{10}$th in fine weather and $\frac{1}{20}$th in very bad weather; and that of common locomotives, working with vertical cylinders, to $\frac{1}{20}$th part of the weight pressing on the rails by the driving wheels; or, taking the friction as equal to 8½ lbs. per ton, or the 263rd. part of the weight, a load equal to $\frac{263}{15}$th or $\frac{263}{20}$th of its weight respectively, or the weight acting upon the driving wheels. The wheels of railway locomotives are sometimes coupled, which nearly doubles the amount of adhesion. The degree of adhesion to the surface of an ordinary road is at least ten times more than upon a railway: that of one wheel of a road locomotive is generally found sufficient; but in passing up a very steep hill another is sometimes fixed)—which is greatest when the road or rails are either quite dry or thoroughly wet, the surface then being most free from obstruction: when partially wet it is much reduced, as the wheels are more apt to catch up the dust.—The other description of adhesion is artificial; thus the surfaces of some bodies are brought to adhere together by the use of glue and other tenaceous substances: the adhesion between two flat pieces of glass or brass, when smeared with grease and rubbed together, is very great.

ADIT, DAY LEVEL, or SOUGH (in mining), a subterraneous gallery or passage, extending from the lowest convenient point in a valley through a hill into a vein of metal, forming the entrance to a mine, by which the water and minerals are conducted, or the miners enter and leave

it. Adits are either walled or timbered where the soil is bad, and they do not always run in direct lines; they also only occasionally form the entrance to the mine. The water of several pits is frequently received by one large adit, extending many miles. An air-shaft is also sometimes termed an *adit.*

The horizontal line at the upper part of the cut represents the adit.

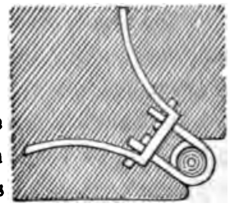
Air-Escape, a contrivance for passing the air from water-pipes, without allowing the escape of the water; the air would otherwise collect in the higher levels of pipes, and obstruct the passage of the water.

Air-Pump (in reference to the steam-engine), the pump employed in drawing off the condensed water from the condenser, communicating therewith by a pipe at the bottom; the air-pump and condenser are usually of similar capacity, each being equal to $\frac{1}{8}$th of the contents of the cylinder.—*See Steam-Engine.*

Air-Valve (in reference to the boilers of steam-engines), a safety-valve fixed at the top of the boiler, and opening inwards, to prevent rupture from the pressure of the atmosphere upon the sides of the boiler, should a vacuum occur within from the steam becoming condensed, or partially so. The valve is kept shut by a counterweight placed at the end of a lever, in the usual manner. There have been instances of boilers becoming collapsed by the pressure of the air from without.

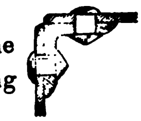
Air-Vessel (as applied to pumps, &c.), a chamber containing air, attached to the ejection-pipe of a pump, and communicating with the pipes through which the water flows; its purpose being to obviate any irregularity in the supply of water, which it effects by its elastic force, the discharge is thereby rendered constant and uniform—for instance, when the water enters, the air within it becomes compressed, and acquires a corresponding degree of elastic force, which it exerts upon the water as it escapes up the pipes, thus a continuous stream is kept in the rising main.—*See Pump.*

Ajutage, a tube fixed at the mouth of a hydraulic vessel for regulating the discharge of water.



ANCHOR AND COLLAR, or GATE HINGES, (sometimes called Collar and Clamp), the hinges employed in hanging lock-gates, &c.

The anchor is usually let into the stone coping, and turned down into it at each end, and well run with lead. The collar is made to fit the hooping on the top of the quoin-post; and is wedged up to the anchor, as may be required, by means of keys, as shown on cut.



ANGLE-IRONS, the pieces employed to join the angles of iron frame-work, as boilers, &c., being rivetted to the iron side-plates.

ANGLE OF TRACTION, the angle formed by the inclination of the traces with the surface of the roadway.

ANGLE OF REPOSE (sometimes called the Angle of Friction), the utmost inclination at which a carriage will stand at rest upon a road or railway, and when upon the least increase of slope it is put in motion by the gravity of its weight; it consequently occurs when the gravity of the load and friction upon the road are equal.

The angle of repose, therefore, varies according to the amount of friction; taking the friction at 9 lb. per ton makes it 1 in 250, or about 21 feet per mile, which is generally considered the angle of repose upon a railway; and taking it at 8½ lb. per ton, gives it at 1 in 263½, or 20 feet per mile.

The angle of repose, upon a turnpike road with a good description of carriage, is about 1 in 40, supposing the road to be perfectly hard.

The natural angle, at which the soil of a cutting or embankment will stand without slipping immediately after teaming, is also called the *angle of repose.—See Friction and Railway.*

ANIMAL POWER. The power of an animal is greatest when standing still, it will consequently support a greater load than it can carry: upon commencing motion its power is lessened, and it continues to decrease in proportion to the velocity of its motion; a speed may at length be attianed at which it cannot carry any

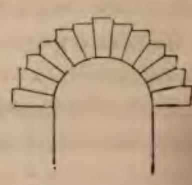
load, the whole of its strength being required to keep up its velocity. An animal has been stated to produce the greatest effect in a given time when moving at $\frac{1}{3}$rd of its greatest velocity unloaded, the load being $\frac{4}{9}$ths of that which it can just move.

As the mechanical effect of an animal is according to the speed of its velocity, and the weight of the load, it may consequently be ascertained by multiplying them together.

Most authorities rate a horse equal to five men: some state it at six, and others at seven.—*See Horse Power.*

Aqueduct, a term applied generally, either to a series of arches over a valley, or to a tunnel through the earth, when either expedient is used for the conveyance of a body of water.

The ancient Roman aqueducts, some of which remain at the present time, were constructed at a great expense, consisting very frequently of several tiers of arches, supporting the water-way, which was intended for the supply of the several public fountains, baths, &c. The supply of water to Rome was considerably greater than the present supply of London, and that of Paris is much less than the latter. The Chirk Aqueduct, in Denbighshire, on the Ellsmere Canal, by Mr. Telford; and the Lune Aqueduct, in Lancashire, on the Lancaster Canal, by Mr. Rennie, are among the most celebrated aqueducts of modern times. The water-ways of modern canal aqueducts are usually formed of plates of cast iron rivetted together. The ancient aqueducts were not used as canals for the purpose of navigation, as those of the present time, but for the conveyance of water for the use of the people.



Arch, a certain arrangement of overlapping wedged-shaped stones or bricks, usually commencing from two fixed points or abutments, the beds radiating and meeting in the centre, thereby forming an equilibrium, when properly constructed, upon the

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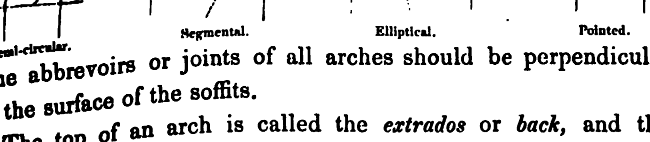
removal of the wooden frame or centre upon which the arch is turned.

Arches are of various shapes—as

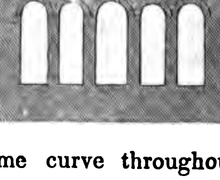


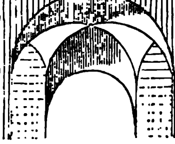
Semi-circular. Segmental. Elliptical. Pointed.

The abbrevoirs or joints of all arches should be perpendicular to the surface of the soffits.

The top of an arch is called the *extrados* or *back*, and the underside the *intrados* or *soffit*; the line from which they commence is called the *springing-line*, and the first arch stones on each side, the *springers* or *reins*, the which rest on the *imposts*, or *abutments*. The extreme width between the springers is called the *span of the arch*; and the rise of the curve in the clear, the *versed sine*. The highest portion of the arch is called the *vertex* or *crown*, and the centre course of voussoirs, the *key-course*.

The side portions of all arches, extending from the crown to the springing, are termed *haunches* or *flanks*; and all arches should be well sustained by backing, carried up on the haunches. The walls built on the haunches are called *spandrel-walls*; and it is customary to carry up spandrel-walls with small arches turned over between them, termed *relieving arches*, upon the backing of arches of great span, for the purpose of preventing any irregular pressure of earth upon the same. Arches are also either cylindrical or groined, the former being an elongation of the same curve throughout its length, and where intersected by other arches cutting across it transversely, the point of junction is termed a *groin*, such being described as *groined arches*.





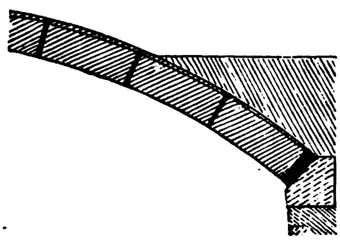
Groined Arch.

An arch, equally balanced in all its parts, is called the *arch of equilibrium*, which is of similar strength throughout, or

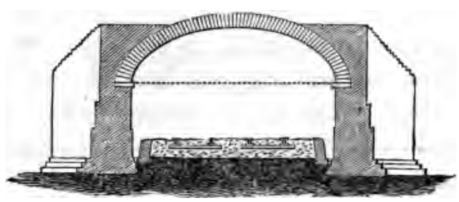
not more inclined to fracture in one part than in another. It is found sufficient, in the practice of bridge-building, if the arch of equilibrium be comprised within the boundaries of the voussoirs, without forming the extrados and intrados of the necessary form, to constitute the same.—*See Arch of Equilibrium.*

The introduction of railways has led to numerous investigations on the best system of building arches, and very fine specimens are to be seen on most lines. The stone arch over the River Dee, at Chester, is the largest stone arch in the world, being a segment of 200 feet span and 41 versed sine: and the centre arch of new London Bridge is the largest elliptical arch, being 152 feet span and 29 feet 6 inches rise. The construction of brick arches should approximate as closely as possible to those of stone; in the common mode of building them the innermost courses of bricks are laid very close, and pieces of tile or slate are filled in the outer parts of the joints; the bricks are, in other instances, laid in separate rings, which system remedies the want of key in the former, but is defective from the want of connection between each ring; it is therefore best to employ *built voussoirs,* by which the key is maintained throughout the whole thickness of the arch: this plan may be said to unite the advantages of each of the former methods, and it is somewhat followed in the construction of the arches on the Blackwall Railway, as shown on the cut *(see next page)*: the lines taken through the arch represent heading-courses laid in mortar to allow for settlement. Brick arches, of very great span, have been lately erected: those over the Thames, at Maidenhead, on the Great Western Railway, are 128 feet span and 24 feet 3 inches rise, and are the largest yet erected; they are turned in cement: the building of brick arches in cement undoubtedly strengthens them, yet, as the remainder of the erection is generally carried up in mortar, an unequal settlement naturally follows, and consequent fracture, unless a proper provision be made for the same. Elliptical arches are therefore not unfrequently turned in mortar, from the springing to the haunches, and the remainder finished in cement; the

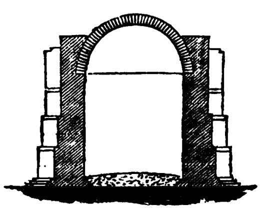
arch is thus enabled to accommodate itself at the mortar joints to any pressure it may receive from the spandrels, or from any sinking of the abutments, which it may do without impairing its strength or effect; sometimes a small portion only of the centre of an arch is turned in cement, in other cases a course of stone is carried along the haunches of an elliptical arch to strengthen it. There are some segmental arches on the Blackwall Railway built of brick, with a span of 86 feet and a rise of 16 feet, which are turned in cement in old English bond (the most general method of turning arches being in half-brick rings); there are three courses of bricks taken through the whole thickness of the arch (4 feet 3 inches) upon each side, their lower beds and cross joints being laid in mortar, also the three courses next the springing of the arch. Some engineers consider it a good plan to lay in the lower courses of the bricks dry, and grout them together, as it gives the bricks a more equable strain.



In reference to railway arches, it may be stated, that the



Transverse Section.



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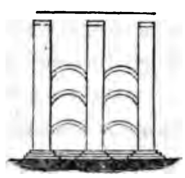
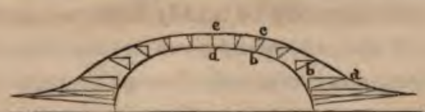


Elevation of back.

general size of the arches for occupation bridges over the London and Birmingham Railway, is 30 feet in width and 17 feet in height to the crown; elliptic arches being adopted, having a rise of 9 feet, as shown on cut; and the arches under the railway are made 15 feet wide, and of various heights, according to that of the embankment. The arches erected over the metropolitan roads by railway companies are required by their acts to be 30 feet wide and 18 feet high, in the vicinities of towns, which is not too much, but 16 feet is generally sufficient for turnpike roads. The extreme height of Temple Bar, London, is 17 feet 9 inches, which is not sufficient for some of the waggons to pass under. A load of hay is from 16 to 17 feet high. The parliamentary guage for the height of luggage upon a stage-coach is 9 feet 9 inches. Arches are also sometimes formed of iron, also of wood.—*See Arch of Equipollence, Bridge, Catanarian Curve, and Centre of an Arch.*

Arch of Equilibrium, an arch equally balanced in all its parts, and capable of standing of itself without the assistance of abutments. The accompanying sketches represent a semicircular arch of equilibrium, and an elliptical one, according to the theory of Mr. Ware. In each case the intrados and direc-



tions of the beds of the several voussoirs are given, also the thicknesses of the crown; therefore, by making *b*, *c*, equal in each case to *d*, *e*, and parallel thereto, and *a*, *c*, respectively horizontal to it, the intersection at *a*, *a*, *a*, *a*, will give the line of curve for the extrados.

As an arch of equilibrium can stand of itself without abutments, it consequently follows that it would be able to sustain a greater weight than an arch formed in a different manner; yet, from the time occupied in working the backs of the arch-stones to the requisite form, it is seldom followed in practice.

Arch of Equipollence, an arch whose several parts are prevented from following their natural directions towards the centre of the earth by mutual opposition. An arch may be equipollent from either of the two following causes: 1st, from the relation of the weight of the several voussoirs forming it, as in the arch of equilibrium *(see Arch of Equilibrium)*; and 2ndly, from the continuity of the several stones alone, the thrust from the crown being transferred from one stone to the other until it is received by the abutments.

Architecture, the art of constructing and building edifices: all the several erections connected with civil engineering partake more or less of architecture.

Arris, the angular line formed by the meeting of two surfaces, constituting an edge; the term has more especial reference to the angles of ashlar masonry.

Arrow (in surveying), a pin employed for marking the chainage, one being placed in the ground at the extremity of every chain.

The arrows are ten in number, and are made of large iron wire, about 16 inches long, with a loop at the top of each, sufficiently large to admit of the finger; a piece of red cloth is sometimes tied thereto, that they may be readily discerned in the field.

Artesian Well, the name given to artificial fountains, obtained by boring down vertically through the geological strata of the earth with augers, or other instruments, into some porous bed, for the procuring of water, the springs met with being nothing more than the overflowing of the water which has fallen upon the earth at different times and sunk beneath the surface; thus, after a great drought, wells will frequently become exhausted. They are usually sunk through a deep stratum of clay into one of sand,

and the water often rises to a considerable height, varying according to the elevation of the highest point of the sand, and the amount of pressure exerted upon it by the superincumbent soil; it is desirable to go below the sand into the chalk if it be of a loose nature, as the fine sand is liable to be pumped away with the water, whereby large cavities are left in the earth: there have been many instances of wells becoming useless on this account; the chalk also abounds more with springs.

Artesian wells have been in use in the northern departments of France and Italy for several centuries, although not introduced into Germany, or this country, above fifty or sixty years; they are now much adopted in the metropolis, where they pass through the immensely thick bed of the London clay, and even through some portion of the adjacent chalk: they are also in general use at Paris. The hole is formed by chisels, gauges, and augers, a pole being passed through the handle of the auger, and two men work it round, one at each end, and pressing it down where there is rock; they also turn it round and lean their weight upon it, accordingly as may be required: another labourer is also placed over them, who, by means of a long timber spring-beam, lifts the pole and assists the pecking. A small tin, copper, or lead pipe, is sometimes driven down the hole upon its completion, to exclude the land springs and preserve the water pure.

The practicability of supplying large cities by water derived solely from artesian wells is extremely doubtful; and were it possible, other difficulties are not unlikely to arise, as the water commonly obtained from springs is brackish or hard, and of an objectionable quality for domestic purposes, and it partakes more or less of the nature of the soils through which it passes: the only way of rendering it applicable to domestic purposes is by subjecting it to a state of motion, and exposing it to the air and weather for a certain period of time, the which has the effect of softening it.

In forming wells, it may be observed that it is customary to wall or plank the upper part, as the water will seldom rise to the

surface of the ground: it is, in fact, usual to perform this part of the operation first, the building of such a wall being termed *steining* the well: the wall is first carried up a certain height from the ground upon a strong curb, generally of iron; the excavators then dig out the ground on the inside, and eventually from beneath the ring itself, upon which the whole sinks, by the effect of gravity, and the brickwork is carried up at the top as it is lowered, until it will go no further; another ring is then steined within the first; if the latter should not be able to reach the proper depth the ground is taken from beneath it, and the bricks added at this end, which operation is termed *underpinning*: cast-iron tubing is also much employed for this purpose, several lengths of it being sometimes driven. A windlass, with buckets attached, or pumps are commonly employed to take the water from the level at which it ceases to rise, or bottom of the well, to the natural surface of the ground.

ASHLAR, the term applied to cut stone, which description of masonry is principally used for the facing of structures only. Where great strength is required the ashlaring is carried up solid throughout: tooled work is sometimes called *tooled ashlar*, the former being distinguished by the name of *plane ashlar*.

ASPHALTUM, a hard black substance, resembling pitch in appearance, found in various parts of the globe; upon being broken, the interior presents a highly polished surface, which has led to its being used in making black varnish.

The many cements, known at the present day by the name of *asphalte*, are not composed of this substance, neither are they similar to each other in their compotent parts. The asphalte of Seyssel is a natural combination of asphaltum, and other bituminous substances, with pure carbonate of lime, in the proportion of about 83 of the former to 17 of the latter; and it has been much employed in France and this country for several engineering and building purposes, and has been found to answer very well, not having been affected by either cold or heat.

ASSISTANT ENGINE (on railways), an extra locomotive em-

ployed upon inclined planes on railways, or to assist the heavy trains.

ATMOSPHERIC ENGINE.—*See Steam Engine.*

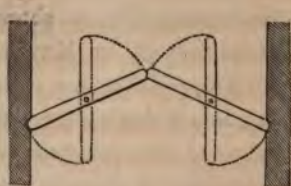
AXLE, or AXLETREE, the pivot, centre, or transverse bar, connecting the naves of the opposite wheels of a carriage.

The axles of roadway carriages are secured in a different manmer to those used upon railways: in the former they are fixed to the carriage bearings, and the ends are fitted into boxes situated in the centres of the naves of the wheels which revolve round the same; each of the wheels are enabled, by this method, to revolve separately upon its own axis, and at different rates of speed as may be required; thus, in turning round, the inner wheels remain stationary, acting as a centre, while the others describe a circle round them. In railway carriages the axles are fixed immoveable in the naves of the wheels, the bearings of the carriages being on the outside, and merely resting upon the same.—*See Friction.*

BACKING.—*See Arch.*

BACKWATER, or SCOURING POWER, the stream of water employed in connection with harbours, to carry away the shingle and prevent its accumulation at the mouth. They are employed where a great quantity of water can be obtained at high tides, large reservoirs being filled at such times, and the water is afterwards discharged on the bar at low water.—*(For observations upon the same see Harbour).*

BALANCE BEAM.—*(See Lock).*



BALANCE GATES, a certain description of flood-gate, much used in Holland; acting upon the following principle, the gates are fixed on a vertical shaft as a centre, and are kept closed by the pressure of the water against them, one side of each being larger than the other; and in order to open them, when requisite, a sluice is constructed in the largest side, which, upon being opened, reduces the area of this side of the gate to less than that of the other side, upo

which the water consequently acts upon the gates, and opens them. Mr. Wickstead has employed balance-gates in connection with the works of the East London Water-works; but each side of his gates are of equal area, a very slight degree of power is therefore sufficient either to open or shut them, whatever the pressure of the water may be, as they are equally balanced.

BALKS, a term applied to long pieces of foreign timber, from about 5 to 12 inches square.

BALLAST LIGHTER, a description of open barge, employed in removing sand, silt, or the like, from the beds of rivers, harbours, docks, &c., which is effected by means of an iron hoop with a leathern bag sewn round the edge of the same, and fixed to the end of a long pole; the hoop is scraped along the bottom of the river, the sand being thereby collected in the bag, from which it is discharged into the barge moored along side of it.

BALLAST WAGGON, the waggon employed in removing earth in excavations, and the like, the which hold about 2 cubic yards, or 2½, or 3 yards at the utmost, even by piling up. If they are filled too full they are apt to tilt: they are usually used without springs, but they are better with them, particularly for those working on permanent rails, as the former increases the wear and tear of the rails, and adds to the expense of maintaining the way considerably. The cut shows an improved form of ballast waggon.

BALLASTING, or METALLING (sometimes called bottoming), a term applied to the covering of roads generally, and to the filling in material, above, below, and between the several stone blocks and sleepers upon railways, &c.; it is laid for the purpose of keeping the road dry, as in the event of water lying upon it, the rails invariably sink, as it causes them to rest unequally.

Ballasting is mostly composed of gravel, broken stone, or the like, and is laid about 2 feet thick on railways, the finished surface of it being usually rather more than 1 inch below the level

of the rails, and it is generally from 6 to 12 inches thick on roads.

A longitudinal drain, 6 inches square, is sometimes laid within railway ballasting, having cross drains, 15 feet apart, communicating with the same, to convey the water into the side ditches. These drains should invariably be used in excavations, and when employed in embankments the water is led down the slopes by drains.

Ballustrade, a series of ballusters situated and fixed under the coping of the parapet of a bridge, &c., the which are not employed in engineering works so frequently as formerly.

Bank.—*See Embankment.*

Bar, a piece of timber or metal placed horizontally, and running across from one part of any framework to another.

Bar (in navigation), an accumulation of sand or shingle at the commencement or mouths of rivers, harbours, &c., being formed by the action of the tides.

Barrel (of a drum wheel), the cylindrical body, or axle, round which the rope is rolled.

Barrel (of a pump), the cylinder or hollow part of the pump in which the piston works.—*See Pump.*

Barrow, a machine generally used for carrying soil in the formation of excavations and other works at their commencement, before a road is formed.

Base Lines (in surveying), the main lines of a survey upon which the correctness of the whole depends; it is therefore necessary to proceed with the utmost care, in the laying out of the several base lines of a survey.

Bat, the name given to a half or other portion of a brick.

Bath-Stone, a very serviceable sand-stone, almost wholly calcareous, although some of it is more silicious. It is extremely soft when taken out of the quarry, but afterwards becomes hard: in setting the stones, it is very essential to lay them in their natural or quarry bed, which remark may be applied to every description of stone, although not to the same degree as with Bath-stone.—*See Stone, Slope, and Soil.*

Batter, the face of a retaining or other wall when built in a leaning position, the top part falling back within the line of base; walls of this description, are sometimes termed *tallus walls*. The batter of a wall is either straight or curved; the latter are also generally commenced straight from the top, the greatest degree of curvature being given to the bottom of the wall.

The average rate of the batter of the walls upon the London and Birmingham Railway is 2½ inches to the foot, and 1 inch to the foot for the wing walls of bridges.—*See Retaining Wall.*

Batter Level.—*See Clinometer.*

Beam.—*See Girder.*

Bearings, as applied to carriages, &c.

The chairs supporting the frame-work of the carriage, the which merely rest on the axles and upon the outside of the wheels of railway-carriages; but they are fixed to the axles of all common road-carriages.—*See Axle, Waggon, and Friction.*

Beetle, a wooden instrument, or mallet, for driving piles, being raised by the help of ropes and pullies: the term is also applied to the rammer used for driving stones into the ground.

Bench, or Berm, a ledge left on the face of a cutting to strengthen the same.

Steep cuttings should always have ledges to support them, particularly in canal work, to prevent the mould from the upper part, falling down into the water; chalk may also be executed at a very steep inclination by their assistance. Ledges are likewise generally made at a change of slope, occasioned by meeting with a different soil.

Bench Marks (in surveying), fixed points left on the line of survey for reference at any future time, consisting of cuts in trees, pegs driven in the ground, and the like.

Beton, a French concretion or mortar, used in the foundation of hydraulic works: it consists of twelve parts of pozzylona, nine of quick lime, six of sand, thirteen of stone scrapings, none exceeding the size of an egg, and three parts of iron scales from the smith's forge; after being well mixed and indurated together, it is broken in pieces, and a coffer having been previously prepared

it is dropped by a proper box into the same, and laid in alternate layers with rubble stones until sufficiently elevated to receive the masonry.

BEVEL GEAR.—*See Gearing.*

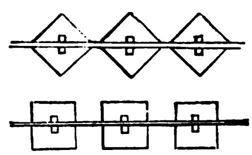
BLAST PIPE, a pipe employed in locomotive engines to convey the waste steam from the cylinders up the chimney, and to urge the fire. Its invention is generally ascribed to Mr. George Stephenson, and it is supposed to have doubled the power of the engines at the period of its introduction.

BLASTING, the operation of detaching and separating blocks of stone or earth from their natural or quarry beds, which was usually performed in former times by the following process: long wooden wedges were driven, in a very dry state, into holes prepared for them, and previously well heated; a quantity of cold water was then poured over the wedges, which, upon becoming thoroughly saturated, swelled and caused a fracture of the rocks. The same effects are now generally produced by the exploding force of gunpowder, which was first used for that purpose in about the year 1820: a hole is first driven into the earth by a jumper, or chisel, which is held in a proper direction by one man while another strike it with a hammer, the former turning his instrument at every blow, by which it is soon made; and it is formed of various depths, from 1 to 3 feet, according to circumstances: if water appears in the hole some stiff clay is crammed in, by which it is absorbed, and the fissures through which it entered filled up; when the hole is of some considerable size, and of great depth, a long jumper succeeds the first, the which is 6 or 8 feet long, and pointed at both ends, with a projecting bulb in the middle, which serves as a handle for the men to lift it up, upon which it is dropped into the hole, and being heavy, it perforates into the rock: a hole, of 5 feet depth, may be formed without much difficulty by a succession of these falls: the gunpowder enclosed in paper is then introduced into the bottom of the hole which is properly adapted for it; a thin copper rod is now connected with it, and some soft impervious substance

crammed into the remaining part of the hole when the rod is withdrawn, by which a vent is obtained, connecting the charge with the touch-hole into which a fusee is dropped and lighted, which completes the operation, when the men retire: crooked pieces of iron are also sometimes introduced into the bottom of the hole to assist in detaching the masses of rock. The natural stratification of the rock is of course attended to, as a horizontal blast will frequently bring down ten times as much as a vertical one.

The blasting of rock under water is usually performed by the diving-bell, the communication with the gunpowder being effected by means of a tin tube: a galvanic battery has also been lately employed for that purpose by Colonel Pasley, and with considerable success; a much greater degree of safety is insured by this system of explosion.

Block (stone, as applied to railways), a foundation or support for the tracks or rails of a railway upon which the chairs are secured. Stone blocks were introduced in place of wooden sleepers, in about the year 1800, and are now in general use; but it is not usual to place them upon embankments until sufficient time has elapsed after their formation to allow for settling, oak or larch sleepers being generally laid down in the first instance. The blocks are about 2 feet square, and are placed in a diagonal direction at the present time, (which was first introduced upon the London and Birmingham Railway), having been previously set square, and at a distance of 3 feet, from centre to centre. When heavier rails are used the bearings are made greater. The 65 ℔. rails on the London and Birmingham Railway are laid 4 feet apart, and the 75 ℔. are made 3 feet 9 inches in cuttings, and 4 feet 6 inches on high embankments, the blocks being 1 feet 3 inches square.



The blocks are set or fixed by a cuddy, consisting of a stand and a timber spring lever, say 20 feet long, by which a labourer raises the block about 1 foot high, while the setter adjusts the

ballasting beneath it, and by a succession of rises and falls it is at length brought to a solid bed, and at the level required.—*See Cuddy and Bearings.*

BLOCK, a piece of wood on which a sheave or pulley is run, and through which the rope passes.

BOILER (in steam-engines), the vessel employed for containing the water to be converted into steam. The boilers employed at the present time are formed exclusively either of iron or copper, or of both, although brick and stone have been used for the same purpose. Copper is considered the best material, its power of conducting heat being nearly double that of iron; a copper boiler of only one-half the superficial contents of an iron one will generate a similar quantity of steam. The power of copper in conducting heat, according to the experiments of M. Despretz, is about 898.2, and that of iron 374.3. Iron is said to possess the greatest cohesive strength, yet manufacturers generally construct their copper boilers of thinner metal, on account of the greater uniformity in the substance of copper plates, and probably for economy, copper being four times the cost of iron; but an old worn-out copper boiler is worth ⅔ths its original value, whereas the value of an old iron one is comparatively trifling, when the cost of removal is deducted; copper has also been proved to be the safest: when a copper boiler bursts, it is merely rent open, but one of iron is often blown to pieces; yet much depends upon the plan of construction: some boilers are also formed of both, as the boiler of a locomotive engine (the description of which will be found under that head).

The great desideratum in the steam-engine appears to be in the formation of a good boiler, one capable of generating the greatest quantity of steam with the least degree of fuel, yet perfectly free from explosion. They should be constructed with a view to provide against rupture, or rather, that in the event of the engine receiving a shock sufficient to rupture the boiler, that it should occur in that part best calculated to prevent loss and fatal accidents, particularly in those for locomotive purposes, small boilers are therefore considered the best. I

large boiler with large tubes of separation bursts, the risk of damage and loss of life is much greater than in the case of a small chambered boiler, as the tubes, being small, act like so many safety-valves, occasioning nothing more than a stoppage. The reason of the boilers of locomotives not frequently bursting is principally owing to the slightness of the tubes, which are thereby the parts soonest affected in the event of any unusual strains, when they merely let the water down upon the grate and put the fire out—their wear is, consequently, very great; but if they were made sufficiently strong to resist, the bursting of the sides of the boiler might be reasonably expected, which would be attended with great consequences.

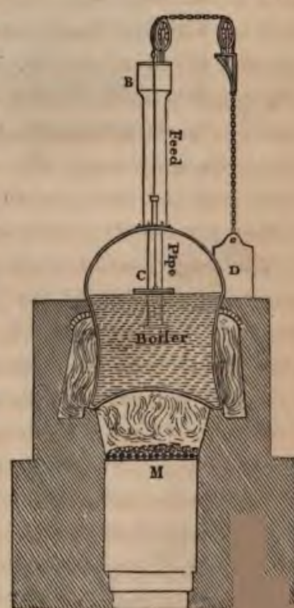
Boilers may be described generally as being of four kinds, viz. 1st, globular; 2nd, cylindrical, with either flat or concave ends, as the Cornish boiler; 3rd, waggon-shaped, having semi-circular top and flat sides and ends, the invention of Mr. Watt: they are, also, sometimes termed *oblong*, or rectangular boilers; and, 4th, the tubular, which is almost exclusively confined to locomotives, on account of its small size and great evaporating capacity; the shape differs from the last two, principally in internal arrangement.—*(See Locomotive Engine)*. The first and second description of boilers are mostly employed for high-pressure engines, their form enabling them to withstand steam of great elastic force, although generally considered to cause a greater expense in fuel.

The waggon-shaped are those usually employed for ordinary purposes, and compensate, by their greater bulk, for the want of the large evaporating surface possessed by the others—they are, also, more adapted for fuel of a slow rate of combustion, and are therefore suitable with all varieties of coal; yet some engineers prefer the Cornish boilers, and maintain that they are most economical.

The boilers of ordinary condensing engines have received various proportions; some engineers give a capacity of 16, and others extend it to 25 cubic feet per horse power; perhaps a medium may be the best, one-half of which should be appropriated for water, and the other for steam; and two small boilers are con-

sidered better than one large one, another being also provided as a reserve: the greatest effect has generally been produced by allowing $4\frac{1}{2}$ square feet of fire surface, or that in direct contact with the fire, and $4\frac{1}{2}$ square feet of flue surface, (or the space interposing between the former and the chimney—the which abstracts heat from the flame and heated air as it passes through), to one horse power; and one cubic foot of water is also evaporated per hour by this arrangement. Mr. Watt allowed 5 feet of bottom surface for the boilers of land-engines per horse power, and 3 feet for marine ones; the space in the latter being more valuable. About one square foot of grate surface should be allowed for one horse power; in marine boilers $\frac{2}{3}$rds of a foot is sufficient, as they consume less coal per horse power than others, the space between the grate bars and the latter being of equal width. From 8 to 10 lb. of coke is generally allowed for each horse power of an engine per hour, although some consume considerably less: 1 lb. of coke was allowed by Mr. Watt for the evaporation of 7 lb. of water.

The following is a representation of a waggon-shaped boiler of the usual construction:—



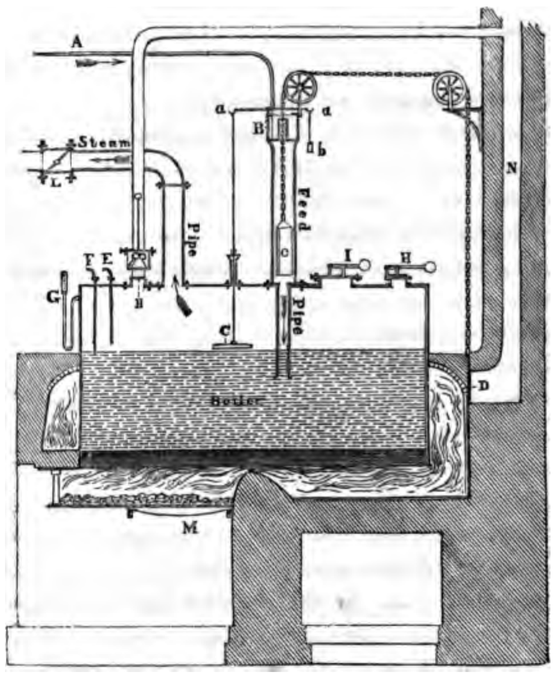
Transverse Section.

A, the supply-pipe from the hot well, which terminates in the cistern at the top of the feed-pipe.

B, the cistern at the top of the feed-pipe, having a valve fixed at the bottom.

C, the float, which is employed to regulate the supply of water to the boiler; the water is kept at the same constant height by its action upon the valve at the top of the feed-pipe, thus:—When there is not sufficient water in the boiler the float sinks, and pulls down the arm

of the lever *a*, *a*, to which it is attached, and thereby opens the valve, as the counter-balancing weight *b*, fixed at the other end of the lever, will only support the float when in its proper situation in the boiler, and at the required level of the water.



Longitudinal Section.

D, the self-acting damper for regulating the consumption of fuel, which it effects by means of a chain connected with a weight situated in the feed-pipe. Now as the force of the steam acting upon the surface of the water forces a portion of it up the feed-pipe, so is the weight within it raised or depressed, varying according to its pressure; the which motion is communicated to the damper, which opens or closes the aperture of the flue of the furnace accordingly, whereby the draught, and consequently the fire, is regulated: the damper is so adjusted as to exactly balance

the weight when the latter is immersed in the water to a suitable depth.

E and F, the gauge-cocks.—*See Gauge-cocks.*

G, the steam-gauge.—*See Steam-gauge.*

H, the safety-valve. This valve can be regulated by the engineer.—*See Safety-valve.*

I, the internal or atmospheric safety-valve, opening inwards, and fixed in the top of the man-hole or inlet into the boiler, for the purpose of cleaning. *See Air-valve.*

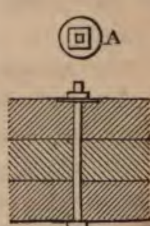
K, the lock-up safety-valve, which cannot be regulated by the engineer. A pipe is shown at the top which leads the steam that escapes into it to the flue, or into the air, as the case may be.

The steam passes from the boiler through the steam-pipe; a valve being placed in it, called a *throttle-valve,* L, for regulating the amount of steam to the cylinder.

M, the furnace-bars.

N, the flue.

There are steam-engines which work with a pressure of 18 or 20 ℔ upon a square inch of the boiler, and others which have upwards of 200 ℔.: but it does not follow that the steam in the cylinder is of equal pressure, it may not be one quarter of that; a reserve is therefore always ready, the supply being regulated, in stationary engines, by a contrivance termed the *governor,* which operates upon the throttle-valve, and by the engineer in locomotives; which process is sometimes called *wiredrawing* the steam. The strength of low-pressure boilers should be twice the regulated pressure on the safety-valve; and high-pressure boilers should be proved to at least three times their working power.


A, the Washer.

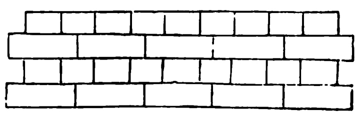
Bolts (iron), the pieces of iron used for securing framing together, and much employed in timber-work; they are formed of wrought iron, either square or cylindrical, with a square head at one end and a screw and nut at the other; a plate of iron, termed a *washer* (A, in the cut), being interposed between the surface of the wood and

the head and nut, to protect the former from damage during the process of screwing up.

BOLSTERS, the pieces of timber used in the construction of the centres of arches, and running across from one rib to another, for the purpose of supporting the voussoirs. A piece of timber, employed in a somewhat similar manner to a corbel, is also termed a ***bolster;*** the which are much employed in timber bridges.—*See Bridge.*

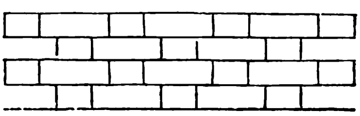
BOND, the union or tie of the several stones or bricks forming a wall. The great principle in all bond is to provide against settlements: the vertical joints of a course should, therefore, be exactly midway between those below—in other words, ***break joint*** with them; and in no case should the joints of one course be carried up over those of the one below it.

The bricks or stones lying lengthways, in the longitudinal direction of the wall, are called ***stretchers;*** and those placed lengthways across the wall, ***headers.***



Old English Bond.

Bond may be described generally to be of two kinds, viz. English and Flemish. In English bond the courses are alternately all headers and all stretchers, and when the backs of each course are laid alternately header and stretcher, it is called Flemish Bond; this description of tie is also known by the name of ***header and stretcher***, particularly in stonework.



Flemish Bond.

Old English bond is much the strongest, the tie being continued throughout, yet Flemish bond seems to be preferred, simply on account of its external appearance; the tie is confessedly inferior to the former, arising from its shortness; a far greater number of vertical joints in the interior of the walls is also consequent upon this plan, whereby the walls are rendered more

liable to split longitudinally, the face-work not being tied into the interior. English bond may likewise be described as the simplest in execution, and the least wasteful. The Romans employed bond of this description in their brick buildings.

The term *perbend,* or *thorough,* is applied to the heading stones forming a wall, when they are carried through the whole thickness, and the term *binder,* when they reach through only a part of that distance.

Bonnet, a hole formed in iron pipes, and furnished with a sliding lid, for the purpose of cleaning out the inside when requisite.

Booms, the pieces of timber connected with fender-piles, and employed to protect coffer-dams and the like from the effects of shocks from vessels, &c.: they are usually secured to the piles by chains, and rise and fall with the tide.

Boning, the operation of finding a line parallel with the horizon without the use of an instrument, but by means of the eye only. It is much practised by workmen in building walls, filling in earth, and the like.

Boring, a vertical sinking, made in the earth by an auger, or other instrument, for the purpose of obtaining water, instead of sinking wells, and for other purposes.

Borings are required to be made on the line of a proposed railway or canal, previous to drawing up the necessary specification and estimate of the works, including the cuttings, foundations for bridges, &c.

Bottoming.—*See Ballasting.*

Boulder Paving, a description of paving consisting of round pebbles or boulders.

Boulder Walls, walls composed of boulders and flints set in strong mortar.

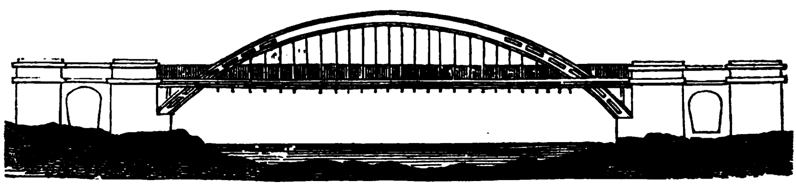
Boundaries (in surveying). In making a survey, the boundaries of the counties, parishes, and the several estates, are required to be marked correctly thereon; in ascertaining which, it is generally found necessary to procure the services of local parties well acquainted with the same.

In the case of property divided by hedge and ditch, the brow of the ditch is generally the boundary; which, of course, forms the line to be measured. In some districts the roots of the quicks, or the foot of the bank, forms it: a width of 15 links is usually allowed for a hedge and ditch, and 6 links for ditches between neighbouring estates, and 7 for those nearest roads, &c., *i. e.* from the roots of the quicks.

Bow-string Bridge, or Tension Bridge, a kind of suspension bridge, the roadway being suspended from wrought-iron rods; but, instead of the usual suspension chains, cast-iron segments are thrown across the ravine, or river, as the case may be, the which are rested on proper abutments upon each side.

Mr. Leather, C.E., was the first who applied this principle on an extensive scale, the two bridges erected by him at Leeds being after this plan, the which have a very elegant effect, and fully answer the purpose intended; they each consist of two segments, the carriage-way being situated between them, and the footways are on the outside.

The Monk Bridge was executed first, the span of which is 112 feet; the other, erected at Howslett, is the largest, being 152



Bridge at Howslett.

feet span, and the rise of the arch is 33 feet, the total height above the level of the water is 43 feet, the width of the bridge is 33 feet, and its cost did not exceed £4,200.

Brake, or Convoy, the drag applied generally to the wheels of carriages to check their velocity in passing down hills, by means of friction. The brake attached to railway carriages consists of a piece of wood, which is pressed upon the rim of the wheels of the carriages by a hand lever, worked by the brakesman. The brake of the tender alone affords a sufficient resistance to stop a train under ordinary circumstances. The term is also used

in reference to the contrivance for arresting the motion of machinery, which is effected generally by a simple or a compound lever pressing forcibly upon the periphery of a broad wheel, fixed upon one of the shafts or axles of the machine.

BREAKWATER, a kind of artificial embankment, dike, or rampart, formed of large stones, and erected for the purpose of protecting the entrances of harbours, also roadsteads, from the effects of violent winds, by breaking the force of the waves of the sea; the shipping, moored behind them, laying perfectly secure.

The most celebrated works of this description are those of Cherburg, in France, and Plymouth, in this country.

That of Cherburg was the first executed, having been began in the year 1783: the building of the wall was commenced upon upright cones of timber, and each cone was intended to have been about 150 feet diameter at the base, 60 feet at the top, and about 60 or 70 feet high, the depth of water, at spring-tides in the line in which they were sunk, varying from 56 to 70 feet; they were also intended to have been filled with stones to the top, and after allowing some time for settling, the masonry was intended to have been commenced upon them; but a few of these cones only were constructed, when, in consequence of the difficulty of the undertaking, the whole was covered with large stones, thrown in at random. This breakwater is 10 feet above the highest tides, and has a roadway or platform, 20 feet wide, on the side next the shore, a parapet wall being built upon it, on that next the sea.

The Plymouth breakwater was commenced in 1812, from the plans of Messrs. J. Rennie and Whitbey. It is composed of blocks of stone, $1\frac{1}{2}$ to 2 and 3 tons weight, and consists of a central

Plan of Plymouth Breakwater.

part, 1000 yards long; and two wings, each 350 yards long, directed towards the sea, and forming angles of 158° with the

centre portion. A transverse section taken through the breakwater shows an average base of 290 feet, and the breadth at the

Section of Plymouth Breakwater.

top is 48 feet, with an average depth of water, at low spring-tides, of 36 feet; the side next the sea is sloped in the proportion of 1 perpendicular to 7 horizontal, and the side next the land is 1 to 5; these sides were not intended originally to have had so great a slope, but, in consequence of the violence of the waves during its construction, it was thought proper to increase them, as executed.

A, A, high-water spring-tides. B, B, low-water spring-tides. D, the foreshore.


Section showing the Breakwater Glacis.

Breakwater Glacis (sometimes termed ***storm pavement***), the stone paving next the sea, in pier erections: they are mostly laid upon a slope, or curved, the stones being of sufficient weight to resist the action of the sea.

Breasts, the name given to the bushes connected with small shafts or spindles.

Breast Wall, a wall built up breast-high, as a parapet wall, or a retaining wall, placed at the foot only of a slope.

Brick, an artificial preparation of clay, sand, and ashes, burnt in a kiln, or clamp, and used for building, and for other purposes; good brick earth is also sometimes found in a natural state. A good brick is about $8\frac{3}{4}$ inches long, $4\frac{1}{4}$ inches wide, and $2\frac{1}{2}$ inches thick, when burnt.—(The Act of Parliament which regulates the size of bricks, states, that they shall not be less than $8\frac{1}{2}'' \times 4'' \times 2\frac{1}{2}''$).

Brickwork is measured in London by the rod, and was taken from the original standard of $16\frac{1}{2}$ feet cube, which gives $272\frac{1}{4}$

square feet of 1½ bricks brickwork, or work 1½ bricks thick, as the superficial contents of 1 rod of reduced brickwork. Therefore, as the standard thickness of a brick wall is 13½ inches, there are consequently 306 cubic feet in a rod of brickwork, and a standard rod will require about 4,500 bricks, allowing for waste; but it depends on the closeness of the joints and the size of the bricks, as they sometimes vary a trifle; and 1 rod of brickwork will take 1½ yards of chalk lime, or 1 yard of stone lime, and 2½ yards of sand with stone lime, or 2 yards with chalk lime, for the mortar: 1 foot of reduced brickwork will also require 17 bricks.

As brickwork is generally measured by the yard in the country, it is therefore the general custom of engineers to adopt the latter measure: there are 11½ cubic yards in a rod.

Bricks are usually burnt in *clamps*, or *stacks*, in the vicinity of London, flues being made in the interior to contain the fuel, and they take from twenty to thirty days burning; but they are burned in conical erections in the country, termed *kilns*, which will burn about 20,000 at a time, consuming less fuel and occupying less time than the former method, 48 hours being sufficient for the burning of them in kilns.

London stocks, also those of Manchester, are the most durable. Suffolk bricks are very celebrated for their light colour and even form, also for their close texture, which renders them nearly twice the weight of common bricks. The softest and most porous bricks made in this country, are those of the midland counties.

Bridge, a very common engineering expedient employed for passing over rivers, canals, and roads. Rivers of great width were not often crossed by bridges formerly, but ferries were usually established, at convenient spots, for the purposes of communication (the scites of most river bridges were formerly occupied by ferries), and shallow streams were commonly forded. The erection of a bridge over a river occasions a great increase of traffic in the line of route, as may be naturally anticipated, in common with all schemes for facilitating conveyance.

The bridges employed in modern times are constructed after various methods, but arches are mostly used. In most cases the road is carried over at once by stone or brick arches, or by iron or wood beams thrown across and trussed, according to the span; the road is sometimes suspended from inverted bows by rods, being usually formed of iron, the which are supported upon stone piers at each end, and from thence carried down and secured in the ground, which are called ***iron suspension bridges***—as the Menai bridge; this description is generally adopted where the span is very great. In other in-

Elevation of Menai Bridge.

Elevation of Bridge near Chalk Farm.

stances the road is suspended by rods, or otherwise, from trussed ribs or girders occupying the space of the parapet walls, the which are termed *bow-string*, or *tension bridges*; as the bridge over the Regent's Canal, near Chalk Farm, on the London and Birmingham Railway. The two bridges over the River Aire, near Leeds, may also be cited as bridges of the latter description.

Among modern bridges may be mentioned the Rialto Bridge, over the Grand Canal, at Venice, which was commenced in 1588, by Michael Angelo, and is considered to be a very beautiful structure.

Elevation of the Rialto Bridge.

The bridge across the Seine, at Neuilly, built between the years 1768 and 1780, by Péronett, is a very celebrated structure; it is a level bridge, consisting of five elliptic arches, each of 128 feet span, and 32 feet rise.—*See next page.*

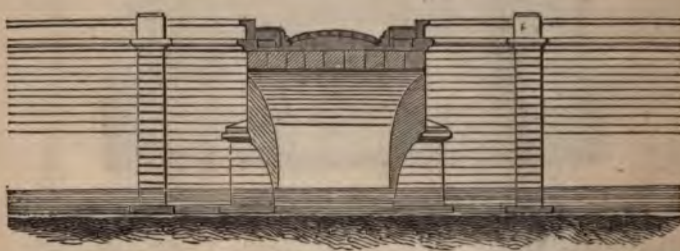
Waterloo Bridge, London, by Mr. John Rennie, is considered a masterpiece, it was commenced in 1810, and is also a level

Details of one of the Arches and Centreing of Waterloo Bridge.

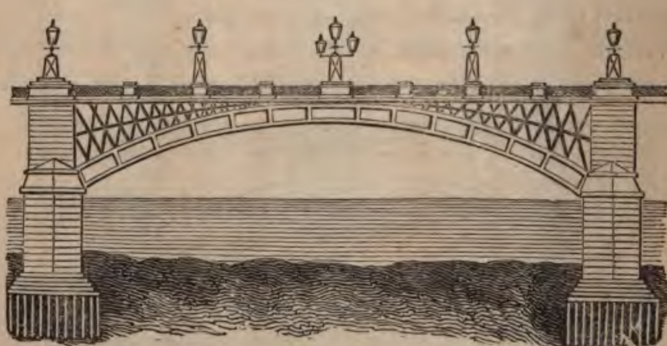
bridge, having nine arches, each 120 feet span, and 35 feet rise, and it is 42 feet 4 inches wide between the parapets.

London Bridge, by the same engineer, is a fine work, and together with the last form excellent specimens of masonry, being

Elevation of one of the arches of Neuilly Bridge.

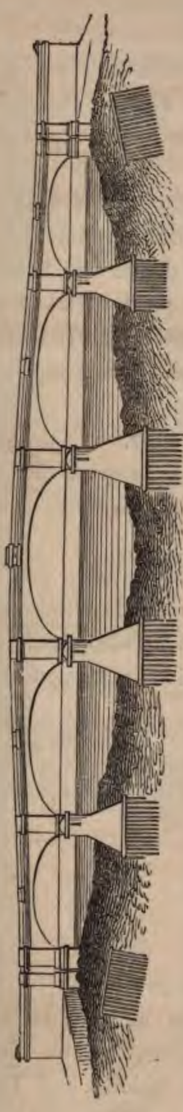


Transverse Section of ditto.

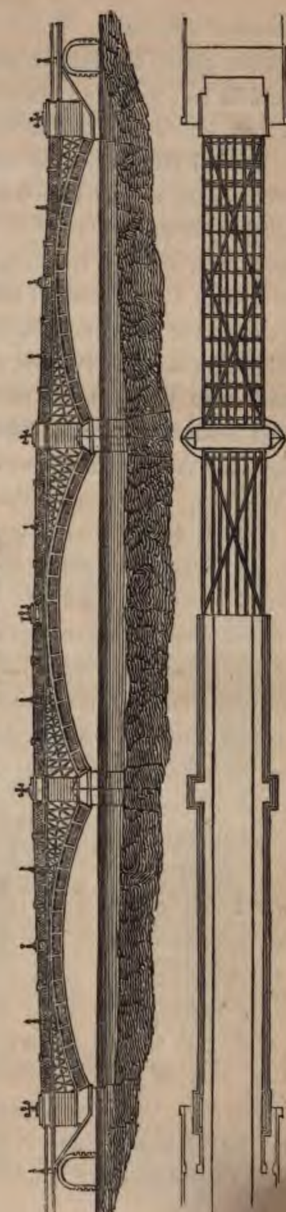


Centre Arch Enlarged of Southwark Bridge.

Elevation of Waterloo Bridge.



Elevation of London Bridge.



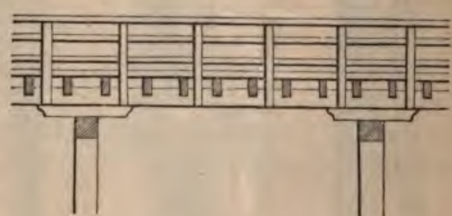
Elevation of Southwark Bridge, and Plan showing Iron-Framing.

constructed of granite. This bridge consists of five elliptic arches, the centre one is the largest elliptic stone arch at present erected, being 152 feet span, and having a rise of 29 feet 6 inches above high water-mark; the two arches next the centre are each 140 feet span and 27 feet 6 inches rise, and the abutment arches, each 130 feet span, and 24 feet 6 inches rise: the width between the parapets is 53 feet.

Southwark Bridge, London, also by Mr. Rennie, is a magnificent bridge, it is formed of cast-iron, supported by granite piers, and consists of three arches, the centre one being 250 feet span, and the side arches 210 feet; the piers are 24 feet thick, and it is 42 feet wide between the parapets: and Blackfriars and Westminster Bridges (which are now undergoing repair), also Vauxhall Bridge, are very extensive works.

The stone bridge over the Clyde, at Glasgow, erected by Mr. Telford, is considered to possess great merit, having seven segmental arches, the centre one being 58 feet 6 inches span, and 10 feet 9 inches versed sine.

Timber bridges have been much more generally employed since Mr. Kyan's invention for preserving timber, as the material offers very great advantages. In wooden bridges of small span, the pieces running from pier to pier are termed *sleepers*, or *string-pieces*, the which support the *cross-joists*, on which the planking is laid: small pieces of wood are sometimes introduced under the string-pieces to shorten the bearing, which are termed *bolsters*, or *corbels*.

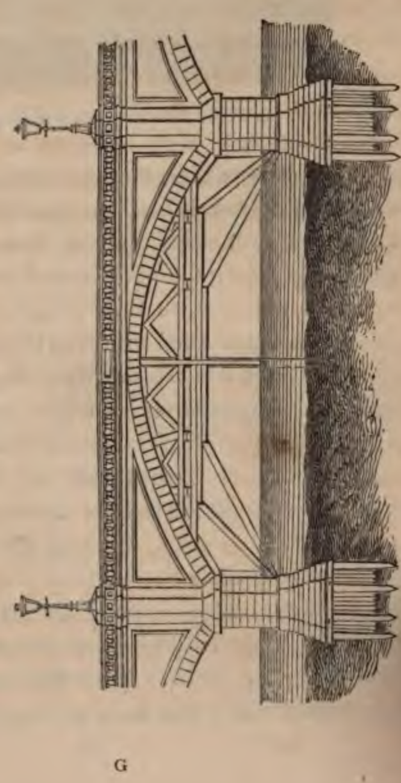


Small Timber Bridge.

A system of forming bridges and viaducts by laminating timber arches, has been lately introduced by the Messrs. Green, upon the Newcastle and North Shields and Tynemouth Railways. The Ouse-burn Viaduct is 108 feet high, and consists of

five arches, each 116 feet span, with two stone arches at each end, 45 feet span; and the Wellington Dean consists of seven arches, each 120 feet span, the height up to the roadway being 82 feet. The piers and abutments are of stone, and each arch consists of three segmental ribs, each rib being composed of thirty 3 inch deck deals, being two deals in width and fifteen in height; they vary in lengths from 20 to 45 feet: the first course is formed of two deals in width, as before stated, bent over a light

Elevation of Glasgow Bridge.



Details of Centre Arch, and Centreing.

centre; the next course consists of one deal and two half ones, and so on, until the whole rib is formed, the ends breaking joint with each other; and they are connected together by 3 inch

Elevation of Centre Arch of the Wellington Dean Viaduct.

oak-trenails, each passing through three of the deals; a layer of brown paper, dipped in boiling tar, is placed between the joints to prevent the wet from injuring them, and the timbers are bedded tightly on it; the ends of each rib are let into cast-iron shoes, which are fixed to the springing-stones of the masonry, and the which are secured with four long iron bolts and run with lead, and the three ribs are connected together by diagonal braces and iron ties; the spandrels are framed as shown in the cut, and the whole of the timber is prepared with Kyan's patent preparation. The Messrs. Greens state the expence at considerably less than one of stone; they have also applied the same principle with a more durable metal, viz. iron, the bars being grooved and tongued into each other.

The wooden bridge, erected by Mr. Bull, over the River Calder, at Mirfield, Yorkshire, for the use of the leading-horses, is also worthy of notice: it is 147 feet 6 inches span, and 11 feet versed sine; the arch is composed of two ribs of fir

timber, with cross stays and diagonal braces, the whole well bolted together.

Bridge at Mirfield.

There have been several arches of large span executed with timber, in Germany and in America—as the Schuylkill Bridge, at Philadelphia, of three arches, the centre one of which is 195 feet span, and the side ones 150 feet; also, the upper Schuylkill Bridge, of the same city, consisting of one arch, 340 feet span, the rise being only 20 feet, the which is the largest arch in the world.

The floods form the principal difficulties to guard against in bridges connected with rivers and canals; and their effect upon the nearest adjacent bridges and arches should be carefully ascertained previous to deciding upon the width of the arches or openings of the intended works. The traffic should be considered next, and sufficient width left for it between the parapets.

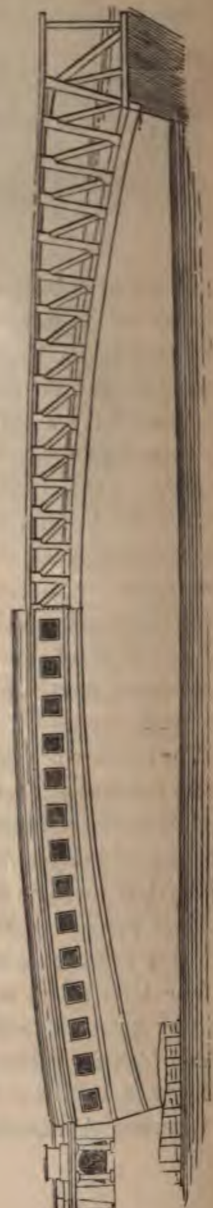
The number of bridges required for a railway varies in almost every instance. There are about two in a mile on the Liverpool and Manchester Railway, exclusive of the viaducts. The proportion of bridges on the Leeds and Selby Railway is about $2\frac{1}{8}$th; but the London and Birmingham does not average $1\frac{1}{2}$ bridges per mile. The mean of nearly 100 railways have been found to average $2\frac{1}{4}$ bridges per mile.

The term *bridge* is also applied to any horizontal beam supporting something.—*See Arch, Bow-string Bridge, Draw-bridge, Iron-bridge, Suspension-bridge, Swivel-bridge,* and *Catanarian Curve.*

BUFFER-HEADS.—*See Buffing Apparatus.*

BUFFING APPARATUS, a contrivance for receiving the shock

Elevation of Schuylkill Bridge. Longitudinal Section.



Elevation of the Upper Schuylkill Bridge. Longitudinal Section.

Section of Bergin's Buffing Apparatus.

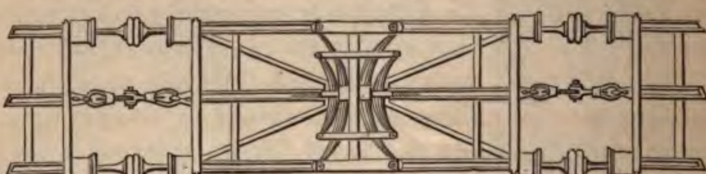
of a coalition between railway carriages, consisting of powerful springs and framing.

The buffing apparatus, first used upon the Liverpool and Manchester Railway, consisted of elliptic iron springs, or bows, of several thicknesses, placed transversely across the middle of the frame-work of the carriage which received the shock of whatever blows or jirks the buffer-heads might receive, by the aid of rods communicating with the same, to which method the following has been considered an objection:—If the several carriages are not loaded equally, the frames do not range upon the same level with each other; and when this is the case, the buffer-heads consequently do not strike each other in the centre, whereby the rods become bent, and the whole apparatus is liable to get twisted: to remedy which, Mr. Bergin, of Dublin, contrived an improved buffing apparatus for the carriages of the Dublin and Kingstown Railway.—*See cut.*

It is supported upon the axles of the wheels, and is totally unconnected with the frame of the carriage, whereby it does not partake of the rise and fall of the latter, according to the weight acting upon the vertical springs; and two strong iron rods are passed through the whole length of the carriage, which rest upon small rollers, to which the buffer-heads are attached, spiral springs being wound round them, which receive the effect of all shocks, by the help of collars formed upon the rods, and the introduction of stops to the springs.

a, *a*, are plates of sheet iron, $\frac{3}{16}$th of an inch thick, and placed 3 inches apart from each other (being fastened together by rivets); they rest on turned bearings on the middle of the axles, and are fixed to an iron frame, *i*, *i*, *i*, *i*, which rests against the cross sheaths, *k*, *k*, *k*, *k*, and framework of the carriage, but are not attached to it. *g*, *g*, are strong iron rods, passing from one end of the frame to the other, the buffer-heads, *h*, *h*, with the dragging-chains attached, being fixed at each extremity; these rods pass through the hollow tubes, *d*, *d*, *d*, *d*, resting upon rollers, *f*, *f*, *f*, *f*, which enables them to move backwards and forwards with freedom. *e*, *e*, are the collars which compress the springs; and *b*, *b*, are the axles of the wheels.

This system is found to answer very well, although there are several modifications of the former description of spring in successful operation, as the following; and Mr. Booth's patent



draw-links are now always employed to conduct the carriages together *(see Draw-link)*. A patent has lately been taken out by Mr. Burstall for a pneumatic carriage-spring, railway-buffer, and elastic-drag, the elastic properties of air being taken advantage of for the same; a flexible vessel, as catouch, is placed, air tight, in a metal cylinder, when the shocks of the buffer-heads are communicated to these elastic springs by means of piston-rods and pistons.

Burn, a provincial name for a brook.

Bush, a piece of metal, usually made of hard brass, and fitted into a plumber-block, in which the journal turns; they are also sometimes termed *pillows*, and the blocks, *pillow-blocks*. The guide of a sliding rod is also termed a *bush*, thus:—A, the piston-rod; B, B, the bush.

Butterfly Valve, a description of clack-valve.—*See Clack-valve.*

Caisson, a large water-tight floating-box, used for the purpose of putting in the foundations of the piers of bridges, &c., which system is generally employed in rapid rivers: a suitable pit is first dug, to receive the caisson; and after one or two experiments are made, to ensure that they perfectly suit each other, it is permanently sunk, and the masonry commenced from within it (the top of the cassion being above high water-mark), and carried up level with the water, when, by a contrivance, the sides are removed, and the pier is left resting firmly upon the bottom grating; and they should be protected by sheet-piling all round, similar to the piers of most river bridges. The bridges of Westminster and Blackfriars were built on caissons; but coffer-dams are generally employed at the present time, as the foundations of both the above bridges appear defective, and are now undergoing repairs.

Camber, a term applied to the rise given to girders and beams in their centre, as an allowance for the sinking, which usually occurs after being hoisted and fixed.

Canal, an artificial cut in the ground, prepared for the reception of water, with which it is supplied, either by means of rivers or springs, &c., thereby constituting a means of internal communication, the which is principally confined to the conveyance of heavy articles.

Canals were not unknown to the ancients, although their revival in modern times is comparatively recent; they were not used in this country, at least since the time of the Romans, until the year 1755, from which period they have spread throughout the whole kingdom; and the competition, presented at the present day by the several railways, has given a great impetus to improvements upon them; the boats have been improved, and new machinery employed at the locks, in order to accelerate the traffic. Locomotive engines have also been tried, to propel the boats upon the Forth and Clyde Canal, by Mr. Macneill, and have

given every satisfaction: the engine runs upon a railway laid down upon the towing-path.

Section of a Canal in Cutting. A, A, the Side Puddles.

Section of a Canal on Level Ground. A, A, A, the Bottom and Side-lining.

The water-slopes of canals can be constructed with a less slope than ordinary earth-work, by reason of the support which they receive from the water, a proportion of $1\frac{1}{2}$ to 1 is generally found sufficient; and the water is prevented escaping by puddle-gutters and side lining, laid about 2 or 3 feet in thickness: where the canal is in embankment, bottom and side puddles are necessary, thus *(see cut)*; and where it is in cutting, or upon a level with the ground, vertical puddles on each side are generally sufficient; as shown on cut.

Brooks are carried across canals by culverts; or, in the case of water being required for its use, and the brooks afford clear water, it may run into a side basin to settle, and from thence passed into the canal, by proper sluices.

The sides and bottoms of a canal are sometimes obliged to be walled throughout, owing to the filtering nature of the soil, the which is after-

wards lined over with good earth, to protect it from the effects of the boats, hooks, &c

In the practical execution of canals, a contrivance, called a *lock*, is usually resorted to, in order to convey the boats from one level to another; the several distances between them being termed *reaches*.

The resistance upon canals is generally allowed to be in proportion to the square of the velocity, provided the depth of immersion remains the same; but if the vessel rises up in the water by reason of the velocity, the resistance is lessened: thus, in some recent experiments made upon canals, it was found, that, after a certain speed, the power of draught was diminished instead of increased, which was caused by the gradual rise of the boat out of the water, owing to its particular construction. A like effect is also supposed to take place with steam-boats.

The power of draught of a horse upon a canal has been stated to be from 20 to 30 tons, at about two miles an hour; and a horse can draw a greater weight on a wide canal than on a narrow one, viz. about $\frac{1}{5}$th more.

The following Table will show the cost of conveying goods and passengers upon canals, at different rates of speed, according to Mr. Macneill's tables :—

Description of boats.	Rate of speed, in miles per hour.	Resistance, per ton, in lbs.	Cost of haulage, per ton per mile.	Cost of boat-hire, &c. per ton per mile.	General expenses per ton per mile.	Aggregate charges.	
						Useful load, per ton per mile.	Gross load, per ton per mile.
			d.	*d.*	*d.*	*d.*	*d.*
Slow boats	2½	2.73	0.18	0.32	0.86	1.36	1.02
Fly boats.	4	7.07	0.5	0.66	2.34	3.5	2.275
Swift boats	10	56.8	0.275 per passenger, 3.5 per ton.	- -	9.7	1.08 per passenger, 13.25 per ton.	10. per ton.

The following Table gives the comparative cost of goods and passengers on canals and upon railroads, both with horse and locomotive power on the latter :—

CANALS.—HORSE POWER.				RAILWAYS.—HORSE POWER.				RAILWAYS.—LOCOMOTIVE POWER.				
Rate of speed in miles per hour.	Resistance, per ton in lbs.	Cost of haulage and boat-hire, per ton per mile.	Cost of conveyance, per ton per mile.	Rate of speed in miles per hour.	Resistance, per ton per mile.	Cost of haulage and carriages, per ton per mile.	Cost of conveyance, per ton per mile.	Rate of speed in miles per hour.	Resistance, per ton in lbs.	Cost of haulage and carriages, per ton per mile.	Cost of conveyance, per ton per mile.	Charges of conveyance, per ton per mile.
2½	2.73	0.5*d.*	1.36*d.*	2½	8.5	0.75*d.*	1.65*d.*	8	8.5	0.565*d.*	1.065*d.*	1.065*d.* 1.565*d.*
4	7.07	1.16*d.*	3.5*d.*	4	8.5	1.127*d.*	3.627*d.*	12	8.5	0.727*d.*	2.138*d.*	3.5*d.*
10	56.8	0.275*d.* per passenger, 3.5*d.* per ton.	1.08*d* per passenger, 13.25*d.* per ton.	10	8.5	0.25*d.* per passenger, 2.24*d.* per ton.	1 to 1.5*d.* per passenger, 15*d.* per ton	20	8.5	Haulage. 0.25*d.* per passenger, 0.73*d.* per ton.	0.675*d.* per passenger, 2.855*d.* per ton.	1*d.* to 1½*d.* per passenger, 12.37*d.* per ton.

See Lock, Lock-gates, Clough, and Elbow.

CARRIAGE, a seat formed in any framing, and adapted for the reception of a shaft or axle, in which the latter revolves.

Carriage (railway). The carriages employed on railways are built in a variety of styles, and are usually mounted on wooden frames situated above the wheels, the bearing of the axles being on the outside of the same; high wheels are, therefore, very inconvenient: they are connected together by a draw-link, or chain. The patent draw-link, by Mr. H. Booth, is now much employed; the carriages are also protected from the effects of shocks that might result from their striking against each other by the buffing apparatus.

The employment of low-bodied carriages is a great preventative of serious accidents, as they preserve their equilibrium better than high ones; they are, therefore, particularly suitable to viaduct lines, as the Greenwich Railway, where they are upon Curtis's improved plan, the bodies being suspended from the springs, instead of being placed on them: a less draught is also produced upon the engine by them, as a train of low-bodied carriages will approach nearer the line of traction, which is situated at the level of the rails.

The first-class railway carriages are extremely convenient, and costly: perhaps those on the Great Western are the most perfect, being from 18 to 21 feet long, and 8 feet wide, and of sufficient height for a person to walk about in; the second class are not so well fitted up; and the third class, when employed, are generally open at the top and sides.—*See Axle, Bearings, Buffing Apparatus, Wheel, &c.*

Catanarian Curve, the curved line, described by a chain, cord, or other flexible body, when hanging freely from two fixed points, whether they be horizontal or not; which form of curve is considered by some mathematicians to be the best for arches generally.

Catchwater Drains, drains laid along the side slopes of cuttings, the which generally run in an oblique direction, and convey the water into a culvert or cross drain.

Causeway.—*See Road.*

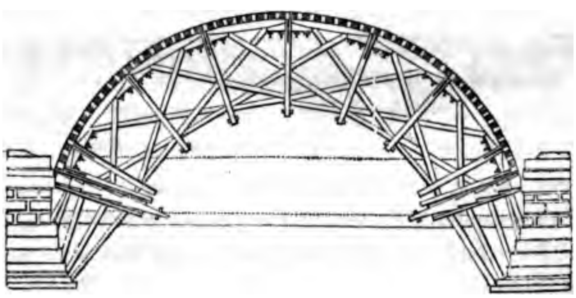
Cement, a composition of several mineral substances, natu-

rally combined or artificially prepared, which become hard upon mixture with lime and a small portion of water. Every kind of stone-lime, when well burnt, becomes a very durable cement; and none other was used in this country until the introduction of roman cement, which is now very extensively employed.—*See Lime, Hydraulic or Water-lime, and Roman Cement.*

CENTRES (of arches), the wooden frames or moulds used in the construction of arches, for the support of the voussoirs or arch-stones, during the course of execution.

The construction of the centres of bridges over rivers is of great importance. In cases where a communication is not required under the arches during the execution of the works, the centres may be constructed with a level tie-beam, which lessens the difficulties attending the same exceedingly; but it is generally necessary to form them in such a manner that the navigation shall not be impeded: where head-room is left above the springing of the arches, such centres are termed *cocket-centres.*

The following cut represents the form of centre used in the construction of Blackfriar's Bridge:—



Elevation of one of the ribs, forming the centre of Blackfriar's Bridge.

The centres used in the construction of bridges were formerly removed piece by pieee upon the completion of the arches: the practice of "striking them" (as technically termed) by driving wedging-pieces between two striking-plates fixed in each side, is employed at the present time, whieh has the effect of lowering the centre, whereby the arch is left standing without support;

[redacted] ery direction simultaneously, [redacted] e or strain. The best way of [redacted] on which the whole of the [redacted] king-pieces resting upon sills [redacted] es by rows of piles driven in resorted to, unless the span of prevent any other mode of ex- particularly safe; but even then less the framing is exceedingly ther.

ly succeeded in erecting an arch Upon the piers being built, the carried forward from each side at equipoise is preserved; and when rive sufficiently near to each other, ; the bricks, of course, to be set in or lathing is intended to be laid The experimental arch above alluded to

distance of 60 feet, it would, therefore, have al arch, 120 feet span, the rise being no more and the whole was built from above by hanging

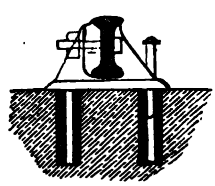
of friction of ordinary cut stone is about 30° with when laid in thin tempered mortar it is from about and with very porous stones laid in full mortar it is therefore a centre is unnecessary for those voussoirs less inclination than the above respectively, while ceeding it must be duly supported until the key-stones

.N, or LAND CHAIN, a measure used in measuring land,

consisting of a number of links connected together by rings. *Gunter's chain*, which is that generally used, is composed of 100 links, and is equal to 66 feet or 4 poles in length: one square chain is 10,000 links, or 16 poles; and 10 square chains 100,000 links, or 160 poles; make one 1 acre.

The chain should invariably be stretched out on level ground and measured, previous to commencing operations, by a 10 feet rod, and if found too long, corrected by removing some of the rings or shortening the links, the corrections being made equally from each end, and from the centre: if any considerable error exists it should be distributed equally over the ten divisions of the chain. It is also customary with some surveyors to mark out a chain correctly on some convenient spot, as a standard to refer to from time to time. Chains, double the length of Gunter's, are also used, and preferred by some, on account of their expediting the work; and 50 feet, also 100 feet chains, may be advantageously employed in a survey, as for streets, roads, canals, and railways, where the superficial contents are not the immediate motive for the survey, it being necessary to return to the 66 feet chain in reducing the quantities to acres.

CHAIR (railway), a pedestal or socket, of cast-iron, used upon railways for receiving and securing the rails, and generally weighing from 12 to 20 ℔. each.

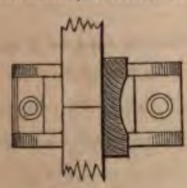


Chair on the Birmingham Railway

The chair for receiving the ends of two rails is termed a *joint*, or *double chair*; and these are of larger size than the others, which are called *single*, or *intermediate chairs*. The chairs are fastened to the blocks by oak trenails and iron pins: a hole, 2 inches in diameter, being first drilled in the block, into which the oak trenails are driven; a $\frac{3}{4}$ inch hole is then bored in the latter by an auger, and the iron pin passed through the seat of the chair and drove securely into the trenail, a piece of felt being introduced between the seat of the chair and the block, to ensure a firm bearing. When sleepers are employed, the chairs are secured to the sleepers by means of iron spikes.

It is very desirable to get such a form of chair as will adapt itself to any settlement of the block without deranging the rail, by either forcing it up or down. Mr. Nicholas Wood, in his Practical Work on Railways, states, that none of the many chairs at present in use, which receive the ends of the rails in their sockets bodily, effect this. A rail which merely rests on the chair at a single point, partly obviates it; but a mere pin, passing transversely from one cheek of the chair to the other, and through the rail, will best accomplish it. This formed an excellent mode of securing cast-iron rails, as they were made in lengths equal to the bearing between each chair only; but it is unnecessary with wrought-iron rails, except at joint chairs, in which case the rails must be halved and lapped at the ends, to allow of the passing of the pin through each of them; although square jointing is employed on most lines of railways, being the cheapest.

The chairs should be formed as little wider than the rails as possible, by which they would be more likely to escape the wheels in the event of an engine running off, and consequently concussion: and the means adopted to confine the rails within the chairs should be as simple as possible: the most general plan of securing them at the present time, is by driving a key, in a horizontal direction, within the space between the cheek and the rail: an



Plan.

Section.

Elevation.

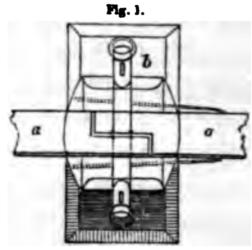
iron key was originally used, but one of oak has been found to answer the purpose best; although there are many other varieties of chairs and fastenings.

View of chair.

Mr. Robert Stephenson took out a patent, in 1833, for the following chair, the principal improvement in which consisted

the self-adjusting seat for the rails to rest on, and the mode of fastening the same.—

Fig. 1.



Plan.

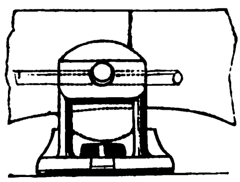
Figure 1 is a plan of the chair, &c., *a a* being the rail.

Figure 2 is an end elevation.

Figure 3 represents a transverse section of the chair, *b b* being the pins through which the cottars are passed to secure them; and *c* the segmental bearing-piece, which lays loose in a socket prepared for it in the bottom of the chair.

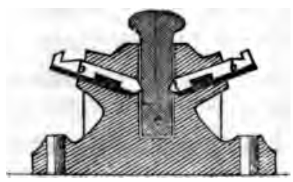
Figure 4 is a perspective view of a joining, showing the halving of the rails.

Fig. 2.



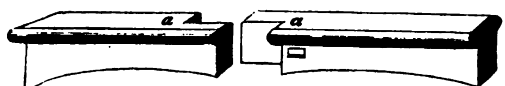
Cross Section.

Fig. 3.



Elevation.

Fig. 4.



View of joining of rail.

CHALK, a calcareous earth, of very soft substance and of a fine white colour, with a yellowish tint when mixed with iron. It is generally found in thick beds, nearly horizontal, with thin layers of flints intervening, and containing a great quantity of disorganized matter. Mr. Kinman gives the following analysis of chalk when in a pure state:—

3	of water.
53	,, lime.
42	,, carbonic acid.
2	,, alum.
100	total.

A, A, Level of the Rails.

Elevation of top.

The Tring cutting, on the London and Birmingham Railway, is taken through this material, in which many fossils were discovered.

Chalk will stand at a very steep inclination, if executed in steps or ledges.

Lime prepared from chalk is very serviceable for building purposes, although it is not generally considered equal to stone lime; but Dorking, and other excellent limes, are obtained from chalk quarries

CHEEKS, those parts of machinery which are double, and enclose other parts.

CHIMNEY, a long funnel or aperture, erected for the purpose of drawing off the smoke from a furnace, and the like, which operates as follows, viz. as the column of air in the chimney becomes heated, and consequently rarified, its specific gravity or weight is thereby reduced, when it effects an escape at the top of the chimney, cre ating a draught up it from the furnace; and the higher the chimney the greater will be the power of draught. The dense black smoke, so often seen escaping from chimneys, is composed of a quantity of unconsumed fuel; it is, therefore, a great object to prevent this waste, by consuming the smoke in the furnace, the pernicious effects of it upon the atmosphere is also thereby removed.

In erecting chimneys, from 70 to 90

feet high, it is a common rule to make them 20 inches square at the top for each horse power of the boiler, giving an area of 400 square inches; and the draught is not improved by increasing the height much beyond 40 or 50 yards, unless the width be increased in a similar ratio.

The two chimneys connected with the stationary engines that work the Euston-square plane, on the London and Birmingham Railway, are 132 feet 4 inches high, and have a very elegant effect; they are nearly 13 feet in diameter at the base, and about 5 feet 6 inches at the top, and the greater part of each is carried up in $1\frac{1}{2}$ and 2 bricks only, the bases being rather more *(see cuts)*.

Chipping-Pieces, the projecting pieces of iron cast on the faces of iron framing, when intended to be rested against each other; the chipping-pieces, therefore, become the points of contact.

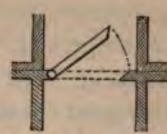
Chock, a filling in piece, or loose block of iron or wood, in any machine or contrivance.

Circumverenter, an instrument, used in surveying, for taking angles by means of the magnetic needle, and employed where great accuracy is not required, excepting in the line of the permanent direction of the needle.

The magnetic needle is enclosed in a compass-box, which is mounted on a pivot in the head of a three-legged stand, the circumference of the box being divided into 360 parts, or degrees, and the latter is furnished with two sights on opposite ends of the meridian line, or 180°.

In taking the angle between two objects with it, the box is turned until one of them is seen through the sights; the number of degrees to which the south end of the needle points is then noted, and the box is again turned until the second object is seen, when the degrees pointed to by the needle are again noted, and the difference between the two numbers is the quantity of the angle.

Clack-Valve, a valve much employed in hydraulics, consisting of a circular piece of leather covering the bore of the tube



in which it is fixed, and moving by a hinge, sometimes consisting of metal, at other times of leather. When two semi-circular valves of this description are employed, and attached to a bar placed across the tube, it is called a *butterfly valve,* which is considered an improvement on the common clack-valve.

CLAYING, the operation of puddling.—*See Puddle.*

CLINOMETER, or BATTER-LEVEL, an instrument employed in measuring the slopes of cuttings and embankments; it consists of a quadrant graduated to degrees, and fixed at the end of a flat bar which is laid along the slopes, and an index turns upon the centre of the quadrant to which a spirit level is attached; therefore, upon the bar being laid lengthways across the slope, and the level set horizontally, the angle of the same will be indicated on the quadrant, as the latter partakes of the motion of the rod.—*See Slope.*

COAL-MINE. The working of coal-mines differs from stone quarries, inasmuch as the latter are generally laid open to the light, and worked from pits at the surface; while those of the former are worked by means of shafts, which are sometimes of very great depth, the coals being drawn up to the surface of the ground by a steam-engine. There are no instances in this country of coal-measures, or beds, lying sufficiently near the surface to be laid bare and worked in open day; nor are they met with in the sides of hills, where the mines could be pushed forward in a horizontal direction.

The method of working coal-mines differs throughout the kingdom, being regulated by the various local circumstances and customs; and that class of civil engineers, who devote their attention exclusively to the subject of coal-mines, are designated *coal* or *colliery viewers.*

In the Newcastle coal-field the amount of capital necessary to work a mine varies from £10,000 to £15,000; they are generally leased from the proprietors, the lessees being termed

adventurers; the extent of the mine is marked out on the surface of the ground, the coal has then to be won, *i. e. obtained possession of*. The risk attending the winning of a field of coal is very great: quicksands are frequently encountered in sinking the shaft, and great quantities of water occur at certain parts of the stratification, generally at about 250 or 300 feet, which is dammed back by tubes, or iron pipes.

The shafts vary in depth from 40 or 50 to 1,000 or 1,200 feet; besides the working shaft, another is also required to draw up the water and ventilate the mine, and these are independent of ventilating-shafts, which are required at every 100 yards distance. The weight of water drawn up is frequently ten times greater than that of the coal. A steam-engine is fixed at the pit's mouth to draw up the coals, and they are also employed below in deep mines with very great advantage, in which case the shaft goes only a part of the way down, when inclined planes are made to the bottom, the which are worked by another steam-engine, fixed at the top of the plane. The coal is worked in galleries laterally, or in the direction of the seams; pillars being left to support the top strata, forming the roof. In Staffordshire the whole of the coal is removed, and the roof allowed to fall in, precautions being taken for the safety of the miners: sometimes the roof does not give way, in which case immense vacant spaces or voids are left, which, in course of time, become filled with water, to the imminent danger of the adjoining mines, as they may accidentally open into one: mines have frequently been drowned by this circumstance.

The presence of fire-damp is another fearful occurrence to which coal-mines are subjected; the coal, in its natural bed, contains a great quantity of free uncombined gas, which is disengaged by the action of the air occupying the place of the strata excavated, and on account of its being relieved from the great pressure exerted upon it by the latter: the lower the strata the greater will be the quantity of gas evacuated, as it partly escapes from the upper beds by means of the fissures: a great

escape of gas takes place under ordinary circumstances, as it is in continual process of distillation from the lower coal-measures, and it accumulates in all the fissures of the stone where it acquires a highly condensed state; these fissures are frequently many miles in extent; and if the miners cut across one of these, or approach sufficiently near, the elastic force of the compressed gas causes an eruption, when it rushes out with immense force, and in vast quantities: these currents are termed *blowers*, and have been known to continue in action from two to three years. Naked lights in mines are wholly inadmissible, as, upon the approach of a candle, the gas instantly explodes with a report like gunpowder, often causing lamentable accidents. Light was formerly obtained in mines by steel mills; a small steel wheel, about 6 or 7 inches diameter, was moved with great velocity, and a piece of flint was presented to it, when a stream of sparks was emitted; the light thus obtained was very feeble, and not altogether free from accidents with certain gases. The safety lamp of Sir Humphry Davy is now universally employed, which consists of a vessel for the reception of the oil, and a cover of fine wire gauze enclosing the wick, which is generally locked on to prevent its removal; upright frame wires surround the cover, terminating at the top by a sort of cap, in which there is a ring for carrying it. The principle of the *davy*, as it is called by the miners, consists in the circumstance of fire-damp not exploding, under any degree of heat, provided flame is not present; and the fact discovered by Sir Humphry, that flame could not pass through short tubes of very fine bore, which the gauze may be said to represent. The lamp subsequently received some improvement in the shape of reflectors placed above it, whereby the light was concentrated.—*See Mine*.

Cock, a sort of revolving valve, fixed in a pipe, for the purpose of stopping the passage of any fluid through it when required.

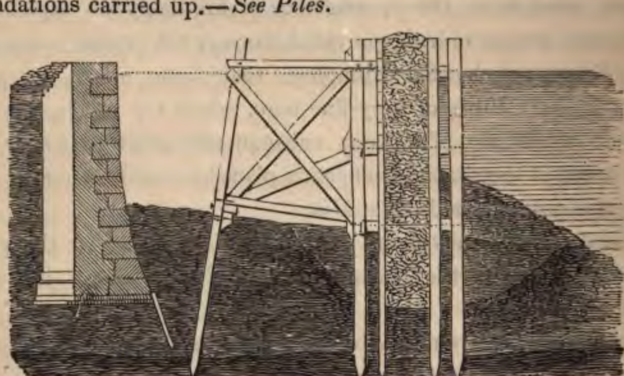
Coffer-Dam, a water-tight enclosure, used in putting in the foundations of bridges, sea and river walls, &c. (which are

circled by the same) when the work cannot be done between the tides, on account of the water constantly covering the site.

Coffer-dams are either of a circular, oval, or oblong form, and consist of one or more close rows of sheet piling, rising above high water-mark, and bolted transversely together, having a large body of clay well punned between each row, with stays, raking-piles, and braces, at the back of the same, to support the pressure of the water on the outer side. Upon the completion of the dam, the water enclosed by it is pumped out, and the foundations carried up.—*See Piles.*

Plan of the Coffer-Dam used for the Piers of Staines' Bridge.

Portion of the Coffer-Dam used for the Piers of London Bridge.



Section of the Coffer-Dam and Wall of the New Houses of Parliament.

COGS, the teeth employed on wheels and racks in machinery, constituting their means of action.

COG-WHEEL, a wheel having a number of cogs placed round its circumference.

COKE, a mineral charcoal, a fuel much employed for steam-engines; it is obtained by burning coal to a red heat, in heaps, properly covered, to prevent exposure to the air: the bitumen, and other gaseous substances, are thus drawn off, leaving a cinder behind, such as is left in the retorts employed in gas-works.—*See Fuel.*

COLLAR, or GLAND, a term applied generally to a circular piece fitting into another, for the purpose of holding it in its place, as a metal plate screwed down upon the stuffing-box of a cylinder to keep the former in its place.

COMPASS, an instrument for determining the angle of any particular object with the meridian, which is effected by looking through sights placed on the margin of the instrument, and then reading off the degrees and minutes pointed to by the needle, the which gives the angle formed with the magnetic meridian; the variation of the same at London, with the true meridian, being about $23\frac{1}{2}$ degrees westward of north at the present time.

CONCENTRIC ENGINE.—*See Rotatory-Engine.*

CONCRETE, an artificial cement, principally employed in the foundations of structures: it is composed of good lime, gravel, and sand, in the proportion of about $\frac{1}{7}$th to $\frac{1}{9}$th of lime, and it should be laid in about 12 inch layers or courses, and pitched down by barrows from a height of 10 or 12 feet, and it should not be disturbed until properly concreted and set, when it may be levelled, the footings laid upon it, and the walls carried up.—*See Foundations.*

CONDENSING ENGINE.—*See Low-pressure Engine.*

CONDUIT, a passage, pipe, or canal, for conveying water, or any other fluid.

CONICAL VALVE.—*See Safety-Valve.*

CONICAL WHEELS.—*See Bevel Gear.*

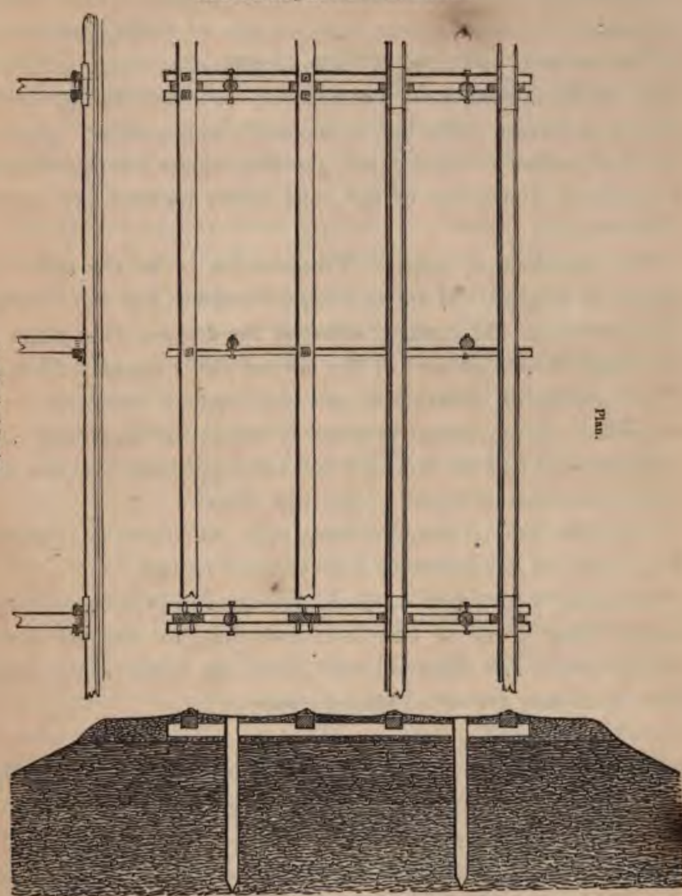
CONSTANT (railway). The term *constant* is applied to certain fixed quantities, both in nature and art, the which are supposed to be conclusive, as the height which a body falls in a second of time, the ratio of the circumference of a circle to its diameter, and as applied to railways; it refers amongst others to the proportion which the tractive power necessary to move a train bears to the weight of the latter, which is stated at $\frac{1}{250}$ to $\frac{1}{300}$, varying according to the perfection of the carriage and railway experimented upon.—*See Railway, Adhesion, and Angle of Repose.*

CONTINUOUS BEARINGS, the method originally employed of laying rails, in this country, consisting of longitudinal sleepers secured to transoms.

The system of continuous timber bearings has been considerably improved, and much used in America, where it has been found very suitable, on account of the abundance of timber in that country, and the scarcity of iron.

The plan of forming the line of the Great Western Railway may also be described as a return to this system. The longitudinal or continuous bearings being from 5 to 7 inches in depth, and 12 to 14 inches in breadth, and laid down in about 30 feet lengths, securely bolted to cross transoms, 6 inches broad by 9 inches deep. There is a double transom at the joinings of the longitudinal beams, and a single one between them, thus they are single and double alternately. Piles of beech are driven within each tract at nearly midway between the rails, 10 inches diameter, and 12 feet long, to which the transoms are secured by horizontal bolts; and there are, therefore, two piles to the double transoms (which are situated between them), and the same number to the single ones. When the piles and timbers are properly fixed and secured together, sand, or fine screened gravel, is beat or packed underneath the longitudinal bearers, until the spaces between the piles are forced upwards, and a firm bed is obtained; and the rails, weighing about 44lb. per yard, are then laid. Mr Nicholas Wood, in his excellent Work upon

Mode of forming the Great Western Railway.



Transverse Section.

Railways, states, that the whole stability or superiority of this railway over other wooden railways, depends entirely "upon the retaining power of these piles."

Details of Rail.

CONVOY (to railway carriages).—*See Brake.*

COPPER MINE. The principal copper mines in this country are those of Cornwall, some of which are of prodigious extent, and the metal is contained in veins, termed *lodes*, which are generally inclined, sometimes considerably so; they are generally from 3 to 6 feet wide, but occasionally much more. After a vein has reached a certain depth, generally somewhat considerable, it gradually diminishes in size, and is not pursued any farther by the miners.

The consolidated mines of Cornwall are by far the most extensive in Europe, and are of wonderful extent and depth, being 1,652 feet from the surface, which is the deepest excavation in the kingdom; the amount of the several shafts exceeds 20 miles of perpendicular excavation, and the various *levels*, or ways driven from them, amount to about 47 miles; the machinery consequently required for drainage and other purposes exceeds any similar combination in the world.—*See Mine.*

CORE, the internal mould or body upon which a tube or pipe is cast, by which the hollow or hole within is formed.

CORNICE, a collection of mouldings, used in bridges and other works, being plain or enriched, according to circumstances: they are sometimes executed with projecting blocks in the lower part, when they are called *blocked cornices.*

COTTAR.—*See Key.*

COUNTER, a contrivance connected with a steam-engine, for the purpose of showing the number of strokes that are made in a given time: it consists of a train of wheel works, resembling that of a clock, and so contrived that at each stroke of the piston-rod a small detent is moved one tooth; it is very useful for regulating the consumption of fuel.

COUNTERBALANCE, or COUNTERBALANCING WEIGHT, a weight employed to counterbalance the vibrating parts of machinery upon their axes, causing them to turn freely, by which a very little power is required to put them in motion, as the counterbalancing weight of a drawbridge, &c. A lever, acted upon by any force, is also frequently returned to its position by a counter-

balancing weight, as in the case of the beam of a single acting steam-engine, &c.

COUNTERFORT, a pier or buttress, generally applied at the back of retaining walls in modern civil engineering, for the support of the same, and likewise for the purpose of forming a tie to the material at the back of the wall. Counterforts are also sometimes carried up upon the face of a wall.

COUNTERSUNK, the term applied to a screw, or other contrivance, when the head is let in flush with the surface of another body in which it is secured; the head is bevelled round on the underside, and the hole is similarly cut to suit it.

COUPLINGS, the means employed of communicating the action of one machine to another; thus, where several machines are put into operation by the same steam-engine, the means of stopping any one of them, and of again restoring its motion without interfering with the others, is effected by couplings, of which there are many descriptions. The couplings mostly used are sliding-boxes, which move longitudinally upon shafts or axles, and engage or lock a shaft which is at rest with one in motion: sometimes they are provided with projecting teeth, called *clutches*, or *glands*, which catch on other teeth or levers, and thus lock the shaft together; at other times they have *bayonets* or *pins*, adapted to enter holes, and the connection is sometimes produced by the force of adhesion only, the surfaces being flat, or conical: the *fast and loose* pulley is, perhaps, the most simple plan, which consists of two parallel band-wheels on the same axle, one of which is fast upon it, and the other loose. A common band may also admit of either motion or rest, accordingly as it is rendered tense or loose. The force of the steam in a locomotive engine usually acts upon two wheels only; when all four are influenced by it, it is done by *coupling* the other two to the driving-wheels.

COWL, a wire cap, covering the top of a locomotive engine chimney, and intended to prevent the escape of lighted flakes of fuel, &c., being made of various shapes, although not employed upon all railways.

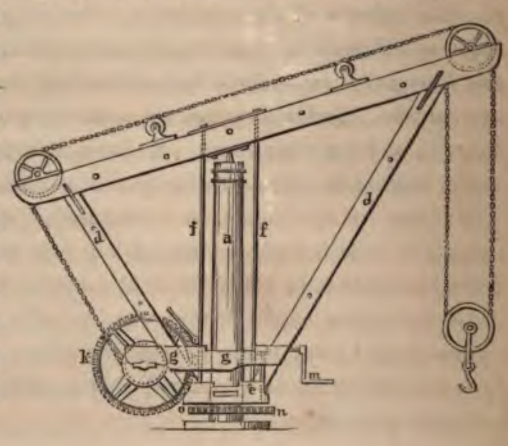
CRAB, a small portable crane, used for raising materials, &c., as the ram of a pile-driving machine, &c.

CRADLE, or COFFER, the frame-work employed in perpendicular lifts, for holding the boats, and conveying them from one pond to the other.—*See Perpendicular Lift.*

CRAMP, a metal tie, used for securing the several stones of a wall together. Cramps are not much used in engineering works, as the masonry is generally solid, and the blocks laid in large sizes, which, therefore, do not require them. Copper is the best material for them, particularly when occurring externally; but iron is generally employed. A vertical cramp is termed a *dowel*, or *plug*; and each description of cramp should be well run, and covered with lead.

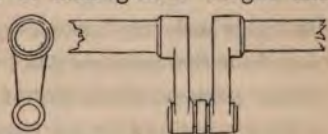
CRANE, a machine employed at wharfs, warehouses, &c., for raising and lowering goods, materials, &c., consisting of a long projecting arm, called the *jib*, having a pulley at the extremity of the same, over which the rope or chain passes, by which the goods are raised, the other end being taken round a barrel attached to the foot of the jib. The great desideratum is the turning of the barrel with the least degree of power; and there have been various plans for effecting the same. The handle of a crane, called the *winch*, should not be less than 2 feet 11 inches, or 3 feet from the ground; and the jib should have an angle given to it of about 45 degrees.

The annexed cut represents an elevation of one of the cranes employed on the Regent's Canal wharf:—



a is an upright pillar of cast-iron, firmly fixed in a foundation of masonry, in the head of which there is a pin which supports the jib *b*, and forms a pivot, round which it turns. *d*, *d*, are two struts supporting the extremity of the jib, the lower ends resting on a collar, which is suspended from the jib by iron rods, *f*, *f*, and passes all round the pillar. The barrel is supported by side frames, *g*; and *k* is the toothed wheel, whereby the barrel is put in action, which is turned by a winch and pinion. The crane is turned round on its pivot by the winch *m*, which operates on an intermediate wheel and pinion, and thereby turns the lower pinion *n*, which works in a wheel *o*, fixed in the base of the pillar.

CRANK, a short arm or lever, fixed to the shaft of any machine, and set in motion by a connecting rod proceeding from some other part of the engine, which has a reciprocating motion to and fro, by which it is converted into a rotatory one. Large fly-wheels are required to be fixed to the shaft where one cylinder is used, and a continuous motion is required, as they carry the crank round the dead points by reason of their greater weight and leverage. A crank usually consists of two limbs joined together by a pin, termed the *crank-pin*. As the cranks of locomotives



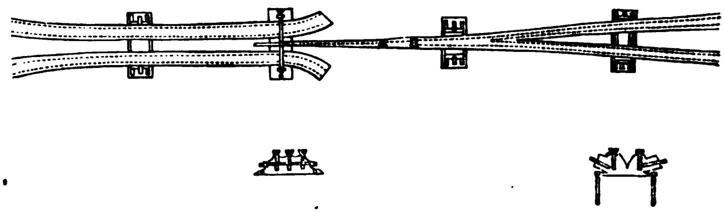
are very liable to fracture, straight axles are sometimes employed, and the wheels are turned by a connecting rod fixed to them on the outside. Some manufacturers cut the entire crank and axle out of a solid piece of iron, which reduces the liability of accidents much.—*See Steam-Engine and Steam-Boat.*

CROSSING (on a double line of railway), the necessary arrangement of rails to form a communication from one line to the other. They are similar in construction to sidings, having switches and crossing-points.—*See Siding.*

CROSSING (level).—*See Level-Crossing.*

CROSSING-POINT, or FIXED POINT or POINT-PLATE (in railway sidings), the points where one rail crosses another, which

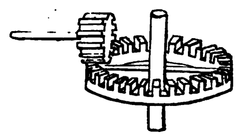
are fixed or immoveable, suitable grooves being left for the passage of the flanges of the carriage wheels on either trackway.—*See Siding.*



Plan and Sections of the Fixed Points used on parts of the London and Birmingham Railway.

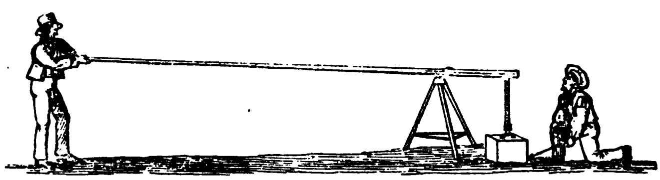
CROSS-STAFF (in surveying), a rod shod with iron, upon the top of which a rectangular cross is fixed, for the purpose of setting off offset-lines square with the principal ones, and similar purposes. It is also frequently divided into ten links, and used for a rod for measuring the offsets, instead of the chain.

CROWN, or CONTRATE WHEELS, a wheel employed for connecting the motion of one axis to another, situated at right angles to it, thus—



Conical wheels are more frequently employed for the same purpose, on account of their possessing less friction.

CUDDY, a three-legged stand, forming a fulcrum, upon which



a long pole is placed, which is used as a spring lever, and employed to lay railway blocks.—*See Block (stone as applied to railways).*

CULVERT, a drain carried under a road, railway, &c., and generally constructed of either stone or brickwork.

Culverts are sometimes used for conveying the water of brooks from the high side of a road to the lower. It is necessary, after fixing the best situation for a culvert, to ascertain the quantity of water that is likely to run in the direction of its course, previous to determining the size of the bore.

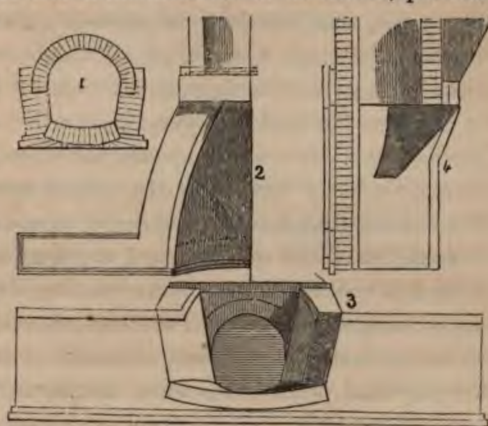


Figure 1, represents a cross section through a culvert.

Figure 2, the half plan.

Figure 3, elevation of mouth.

Figure 4, the longitudinal section.

Curve, a term applied to a bend in a line of road, canal, or railway.

Turnpike roads should be formed as straight and direct as circumstances will allow, and without any sudden bends; but they are frequently obliged to wind round a hill in order to get up it, and a similar expedient is employed in the construction of canals, to preserve the low level.

Sharp curves on a line of railway are highly objectionable, as the centrifugal force arising upon them has a tendency to throw the train off the rails: they should never be laid down with less than $\frac{3}{4}$ths of a mile radius; notwithstanding, many expedients are resorted to of obviating the difficulties attending them: the friction is also increased, on account of the flanges of the carriage wheels rubbing upon the sides of the rails. The peripheries of the wheels of railway-carriages are always enlarged in diameter next the flanges, being made slightly conical, which compensates, to a certain extent, for the extra length of the curve of the outer rail. The tires of the wheels are usually made about

1 inch more in diameter on the outside than on the inside, the breadth of the same being 3½ inches; and 1 inch is allowed upon each side of the rails, in fixing the wheels to the axles for play, by which they are not strained in passing along the curves. An engine, with wheels 3 feet diameter, and of the above description, will turn a curve $\frac{1}{5}$th of a mile radius, provided the outer rail is elevated sufficiently to counteract the centrifugal force, by causing a gravitating power towards the centre of the curve The degree of elevation necessary to balance the load depends upon the velocity with which the train is moving; upon a curve $\frac{3}{4}$ths of a mile radius, and traversed at a rate of 10 miles an hour, it should be .07 of an inch; and at 15 miles an hour .20 of an inch; at 20 miles .36 of an inch; but they are frequently elevated much more in practice. The least objectionable situation for curves on a railway is at the extremities of the line, and the foot of an inclined plane is the most dangerous, more particularly if any portion of it should be in tunneling: the objection also increases with the speed of the train.

A rise of 16 feet per mile upon a curve of $\frac{3}{4}$ths of a mile radius, reduces the speed of a locomotive to nearly one-half; yet, there is a curve of $\frac{1}{4}$th of a mile radius on the Bolton and Leigh Railway, which is daily passed at a speed of 30 miles an hour, and with perfect safety.

CUTTING, a name applied to excavations.—*See Excavation.*

CUTWATER, the lower portion of a pier separating two arches of a bridge crossing a river; they are usually formed of stone, and pointed in front, for the purpose of dividing the stream, whereby it is carried away from the foundations, and of cutting the ice in frosty weather.

D SLIDE-VALVE (in steam-engines), a valve much employed for opening and shutting the communications with the steam cylinder; particularly in locomotive engines: its action will be readily understood by the cut. *a* is the steam-pipe; *b*, the upper passage; and *c*, the lower passage to

the cylinder; *d* being the passage to the condenser or chimney, as the case may be; and E represents the slide-valve.—*See Four-way Cock.*

DAM, or WEIR, a water-tight contrivance, for the purpose of supporting a body of water, and preventing filtration.

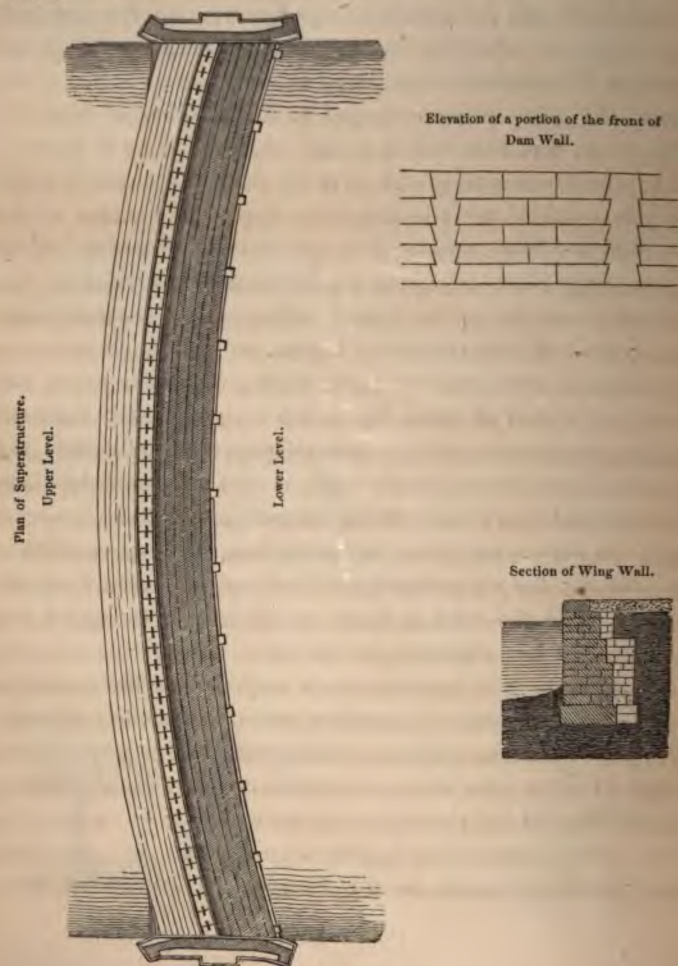
A dam usually consists of a wall, or mole, erected across a river or stream, for the purpose of raising the level of the water by confining it, and which is employed for various purposes, as for irrigation and for ornamental purposes; also for impelling machinery, as water-wheels, in which case the wheel is not placed in the current, but is mostly situated upon one side of the stream, the water being conveyed to it by a channel from the upper level, and after having passed over the wheel it finds its way to the lower level of the river by another channel, and the requisite head of water is constantly kept up by means of the dam, which is furnished with proper means of passing off all surplus water when the supply is greater than required.

Dams should be erected at the broadest parts of rivers, in order to secure a sufficient reservoir of water, as some mills, when at work, require more water than the ordinary run of the stream can afford; by means of these basins the supply is thus rendered regular, and the intermitting nature of the current obviated: the water that accumulates in the night is also preserved by them. The reservoir of a mill is called the *mill*, or *dam-head:* and the larger the surface the better will it operate, but a great depth is unnecessary; the water should run freely over the dam when not required, or in the event of floods, the channel to the mill being provided with side walls and sluices.

Timber framing is very frequently employed in the construction of dams; but masonry is better, and, of course, the requisite precautions must be taken to prevent any leakage of water from above. A thick bed of puddle should be laid next the upper side of the water, protected by a layer of gravel. Dams are usually made in the form of a

segment of an arch on the plan, and the face of the dam wall should be plumb, or battered down very gradually, and the lower level, or foot, being properly paved or planked. In cases where the fall is considerable, it is frequently divided into more than one dam: they are also sometimes constructed upon a moveable principle, and are removed in flood seasons.

The following is a representation of a dam, as generally constructed:—



but with greater accuracy of construction, a heavier engine might pass over the same rails—say an engine of 14 or 16 tons. It was found, in prosecuting the experiments, that the blocks also yielded at the time of a train passing over them, which depression, or disturbance of the block, amounted to from .019 to .021 of an inch when securely fixed; and with hanging and loose blocks it was double, or even triple. And taking one-half of this as resolvable to the middle of the rails brings the deflection of bars, with weights moving over them, to about that of rails with equal weights resting upon them.

DEGREE (in geometry), the 360th part of the circumference of a circle, all circles being supposed to be divided into that number; it is denoted by a small ° near the top of a figure, thus, 36°; each degree is again subdivided into sixty parts, called *minutes*, and denoted by a mark, thus, 25′; and those are again subdivided into sixty parts, called *seconds*, denoted thus ″; therefore, 36°, 25′, 20″, means thirty-six degrees, twenty-five minutes, and twenty seconds.

DEPÔT, or STATION (on railways, &c.). This term is applied to the commencement and termination of a railway, &c.; also to stations for the taking up and setting down of passengers or goods. The additional quantity of rails required for the stations, sidings, &c., of a railway, is very great; it amounted, on the London and Birmingham Railway, to $\frac{1}{10}$th of the total quantity required.

The receptacles for tools and materials on the side of a railway, or road, are also termed *depôts*.

DIAGONAL, a term applied generally to a right line drawn across any figure, from the vertex of one angle to the vertex of another, or across from one corner to the other.

DIVING BELL, an apparatus employed for under water works, somewhat resembling a large barrel without a bottom, or a bell, as the name implies, and is usually of about 5 feet in height, and the same in width, in the clear.

Diving bells are mostly formed of very thick cast iron, and in

one piece, whereby they are air-tight; the weight of metal causes the bell to sink readily, and its substance protects it from accidents; the top has an opening disposed for the reception of a supply of air: thick lenses are also fixed in the upper part to admit light. It has been thought that many under water works, at present executed by means of coffer-dams, and other contrivances, may be effected by the help of diving bells, by which a great saving would be made; and there have been instances of their being employed for such purposes. The piers of the Lary Bridge were carried up by means of wooden diving bells, under the direction of Mr. Rendel, although the stream was very rapid.

DOCK, an artificial enclosed basin, formed for the reception of shipping, of which there are three descriptions, viz. *wet docks*, or docks for the reception of ships at all states of the tide; *dry docks*, so called from their being left dry when the tide is out; and *graving docks* for the repairing of vessels.

Wet docks consist of very extensive basins, communicating with some large river or harbour, by means of locks, and a proper depth of water is always kept up in them, so that vessels are afloat at all times of the tide. The entrance to wet docks is by a basin, with lock and pier-head at its entrance; and this entrance basin is generally connected by locks with two different docks, viz. an *import*, or one appropriated for ships in loading; and an *export dock*, for vessels going out, the quays of which are generally surrounded by warehouses, for the reception of goods.

The wet docks, at Liverpool, were commenced in the year 1708, and they extend, at the present time, to a distance of above two miles along the banks of the River Mersey, and in front of the town, presenting a most striking effect. The Hull docks were commenced in 1774; and docks were also commenced at Bristol, and at Leith: but there was no dock in the metropolis, or accommodation on the Thames, until nearly half a century after a wet dock had been constructed at Liverpool, which is partly accounted for by the superiority of the port of London as a natural

harbour when compared with that of Liverpool. The West India Docks, which were the earliest in London, were commenced in the year 1800, in which the import dock is about 2,600 feet in length, and 400 in breadth, covering an area of nearly 25 acres; and the export dock is of the same length, by 500 feet in breadth, comprising nearly 30 acres. There are, also, other wet docks connected with the establishment; their depth of water is 25 feet, at spring tides, and the whole will contain 600 vessels, from 250 to 500 tons burthen: the warehouses are noble buildings; the tobacco warehouse is the most spacious erection of the kind in the world, being capable of containing 2,500 hogsheads, and the vaults underneath will hold the same quantity of wine; it is said to occupy a space of 4 acres, and is all under one roof. The London, East-India, and other metropolitan docks, are also very fine docks. St. Katherine's Docks were opened in 1828, and are convenient, on account of their close connection with the centre of the city. The machinery employed at the several docks, consisting of cranes, railways, &c., is also very ingenious and perfect. The depredations carried on upon the River Thames previous to the construction of the docks, was immense; they may, therefore, be said to have been of considerable benefit: the ships, also, now lie in perfect security from the effects of storms, while their cargoes are being shipped or unshipped, and the river is kept clear of obstructions, comparatively speaking.

Graving docks are prepared for the reception of vessels that require repairing; they are also known by the name of *repairing docks*, and are formed of dimensions merely sufficient to admit of one vessel, although sometimes large enough for two; they are furnished with a pair of gates next the river or entrance, to keep the water out, the vessel being floated in at high water, when the water is withdrawn by the tide, and the sluices connected with it are shut, and any that may be left within it, is pumped out; proper shores or props having been previously placed against the sides of the vessel to support it.

A description of floating graving dock is employed in the

United States of America, consisting of a hollow vessel or box of framed work, upon which the vessel to be repaired is floated, the water is then pumped out from the interior of the hollow vessel, when it gradually rises, lifting the former out of the water, and leaving the bottom exposed to view. There are, also, other methods for effecting the same end practised there.

Double-acting Inclined Plane (on railways).—*See Self-acting Inclined Plane.*

Double-railed Inclined Plane, an inclined plane having two lines of rails upon it.

Drain, or Ditch, a trough for receiving the water drained from a road, or railway.—*See Ballasting, Culvert, Embankment, Excavation, Fencing,* and *Railway.*

Drainage (for agricultural purposes), the process of diverting and drainingthe water off from bogs, marshes, and lands, subject to be flooded from heavy rains; also for recovering land from the sea. It is recorded, that the drainage of the extensive marsh, which reached from the Thames to Camberwell hills, was continued by the Romans, until, by "drains and embankments," they recovered all the low land in Southwark and its vicinity; and the general method resorted to at the present time is somewhat similar, viz. by cutting trenches to a certain depth below the surface, to carry the water to the lower levels, forming embankments to support it, &c.

According to Dr. Anderson, of Edinburgh, swamps and morasses arise in consequence of the water attracted from the atmosphere, by the summits of hills and mountains, which penetrate through the porous strata, of which they are formed, until its course is arrested by a stratum of clay, or other impervious material, where the water accumulates and stagnates, and at length forces its way upwards through the soil, forming bogs and marshes in the valleys at the foot of the hill. And he recommends that a trench be cut along the base of the hill, extending to the substratum of clay, or other body, which impedes the escape

of the water, and it can then be conveyed away by another drain: faggots or stones may be piled over the trenches, so that the run of water is not disturbed. In cases where the top soil is of very great depth, and the water does not rise in the ditch, he recommends boring for the clay until it is reached, when the water will rise into the ditch. He is supported in this opinion by Mr. Elkinton, who bestowed great attention to the subject about the same time.

In every level country where there is not sufficient fall to carry off the water, mechanical means are obliged to be resorted to, as pumps, syphons, and the like: pumps driven by windmills were very extensively used for this purpose in Lincolnshire formerly; but steam-engines are now substituted, and with considerable advantage. The amount of mechanical power necessary to drain fen land is not so great as commonly imagined, as there are not, generally speaking, any natural springs to encounter; therefore, upon the upland water being enclosed by embankments, and carried into the rivers in their vicinities by catch-water drains, nothing more remains to be removed but the water that descends from the clouds, which has to be raised to the higher level, where it is run off; the lift varies according to the height of water in the river, which is influenced by the tides, floods, &c., but it seldom exceeds 3 or 4 feet, to which about 18 inches must be added, on account of the water lying in drains, and consequently below the level of the ground. The land recovered is generally of a rich and fertile nature; it also possesses the advantage of irrigation; thus, when the country is dry, the sluices from the rivers may be opened, and the earth moistened. The effect produced by windmills would be quite sufficient if they could be depended upon: but steam is preferable, as it generally happens that in cases of much rain there is but little wind; the latter are also always ready, and have been found to be the cheapest, taking all things into consideration.

Mr. Joseph Glynn, C.E., has demonstrated the comparative facility of recovering fenny lands, by drainage, in a very satis-

factory manner: he employs cast-iron wheels to raise the water from the lower levels, which are termed *scoop-wheels*, and are situated in the ditches; these carry the water upwards, being turned by a steam-engine.

In reference to marine drainage, it may be stated, that mere lands reclaimed at once from the sea can seldom be of much value for agricultural purposes, sand materials being naturally the general deposit; but the finer and lighter soils, which are constantly driven down from the alluvial tracts by the tidal process, should be first arrested, the which forms a fruitful supersoil. There are instances existing of portions of a country being now covered by the sea, which was once dry land; and a vast quantity of vegetable matter may be allowed to have accumulated upon such ground, provided the action of the shingle has not reached it; and cases of this kind may be considered as forming exceptions to the above rule.—*See Sewerage, Scoop-wheel, &c.*

Drainage of Mines, the getting rid of the water within the bowels of the earth, arising from springs, and other natural causes; and for the purpose of facilitating mining operations.

The drainage of mines forms a subject of immense importance, the power employed to accomplish the same being frequently ten times greater than that required in conveying the minerals up the pit: the system pursued is regulated by local circumstances. In mountainous countries, and wherever practicable, the method of draining by means of a day-level, or subterraneous channel, is adopted, extending from the lowest part of the mine to the adjacent valley; in other cases, an adit is used as far as possible, and steam-engines employed to pump the water up the remaining portion; and in flat countries steam power is obliged to be used for conveying it the whole of the height up to the surface. The depth of the pump shaft is usually divided into lifts, which, if possible, should not exceed 25 or 30 fathoms, a cistern being placed at each, and the water is raised alternately from one to another; the diameter of the pump is regulated by the power required, and varies from 8 to 16 inches, or 18 at most, and the

length of the stroke is from about 6 to 8 feet, which it should never exceed.—*See Adit and Mine.*

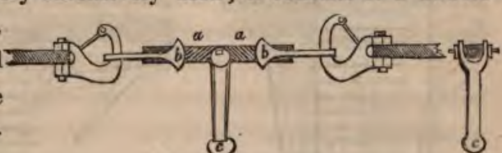
Draining Tiles, the hollow tiles employed in the formation of embankments, to carry off the water to the side drains, being let into the earth, or placed one upon another down the slopes: they require frequent attention, owing to the settling of the soil. A row of drain tiles should be carried through the mounds of fencing at about every 100 yards distance, to convey the water into the side ditches.

Draught (in masonry) the chisel-dressing at the angles of stones, which are generally made as a guide for the regular levelling of the several surfaces.

Draught (in mechanics), the power or force required to put any machine in motion—as a horse-mill, or a coach, waggon, boat, or other vessel.

The depth of water necessary to float a ship, or other vessel, is likewise termed the *draught*.

Draw-Link (railway), a contrivance for securing the several carriages of a train together. The patent railway draw-link, invented by Mr. Henry Booth, of the Liverpool and Manchester Railway, is now very extensively used; it consists of a double-working screw, *a a*, which is attached to the hooks at the ends of the carriages by two long links, *b b*, which are spirally threaded, to receive the screws; and the carriages are screwed up close together until the buffer-heads, *d d*, touch each other, by means of a lever, *c c*, fixed in the middle of the screw; the springs of the several carriages are thus brought into constant play, and an equal elastic pressure is produced at starting, in lieu of the sudden shocks, of such frequent occurrence previous to its introduction. There is a weight at the end of the lever which keeps the cottar constantly suspended, by which the screws are maintained in their prop places.—*See Buffing Apparatus.*



Mr. Booth's Patent Draw-Link.

DROVE, a narrow channel or drain, much used in the irrigation of land.

The term, *drove,* also refers to a description of tooling applied on the faces of hard stones.

DRUM, or ROPE ROLL, a hollow cylinder or barrel fixed on an axle, around which either single or endless ropes or bands are passed, for the purpose of communicating motion to other parts of the machine. The drums used on the inclined planes of railways are generally formed of cast-iron, the rope being wound round their peripheries, by which movement the trains are conveyed along the line.

Drums are also frequently connected with machinery, being fixed on the main shaft, and leather belts are usually passed round them.—*See Inclined Plane.*

DRY ROT, a term applied to that rapid decay in the interior of timber, by which its substance is converted into a dry powder, which issues from minute circular cavities, resembling the borings of worms. Timber once affected can never be restored; there remains no choice but to cut away such parts. It is supposed to arise principally from the timber being used before the interior is perfectly dry; and it also occurs from being placed in confined and close situations where there is not a sufficient current of air.

There have been many attempts to prevent the occurrence of the dry rot, but Kyan's patent preparation is considered the most successful, and it is very generally employed as a preventative for the same.

DRY DOCK.—*See Dock.*

DIKE, a term sometimes used in the same sense as embankment, with this difference, that a hydraulic embankment, and one impervious to water, is alluded to; thus, a considerable portion of Holland is preserved, by works called *dikes,* which is rendered necessary by such parts of the country being below the level of the sea; the consist of a mound, properly sloped on each side, on the top of which there is a road, and a sort of reed is planted on the banks next the sea, which serves to strengthen

them, and the continual deposit of sea warp that takes place further assists them: a second dike is sometimes formed behind the first, as an additional security, the space between them serving as a canal to carry off extraordinary floods.

Dike (mining), a name applied to a kind of faulty vein when occurring of some extent, and which are generally found in a vertical position, intercepting and disturbing the regular strata of the earth; they sometimes consist of clefts or fissures, and extend a considerable distance, being called, according to their elements, as *whin dikes, basaltic dikes, &c.*; at other times they are merely filled with clay, having foreign substances imbedded therein.

The occurrence of dikes frequently occasions great difficulty and expense in mining operations, both on account of the trouble of working them out, and their sometimes containing water, when the works are frequently inundated.

Dynanometer, an instrument invented by Mr. Macneill, and used for measuring the amount of force required to draw either carriages or boats.

This instrument has received various improvements; but even now it answers very indifferently upon railways, and it gives no test whatever of the amount of atmospheric resistance (which is supposed to be considerable at high velocities) on account of being situated between the engine and train, as the locomotive receives the force of the air, but does not communicate it to the dynanometer.

Earthwork, a term applied to cuttings, embankments, &c. The several methods employed in executing earthwork at different parts of the country are very similar. The earth, after being dug, is conveyed by wheelbarrows at the commencement; and waggons, running upon rails, (usually from 30 to 50lb. per yard) are employed as the work proceeds; six teaming-places may be made where the slope equals 2 to 1, which greatly expedites the work; if less, four only can be made: a flat slope can, therefore, be executed, in a certain proportion, quicker than

a steep one. If time is an object, the tip end of an embankment should be made wider than it is intended to be finished, to admit of more roads upon it; and as the work proceeds it may be reduced to the required width, and the soil from it thrown down the slopes: a certain width may, in fact, be allowed for it at the bottom of the embankment. The time of executing an extensive embankment may be reduced one-half, by forming it in two stages, as the works of each may proceed at the same time; and the difference in level is got over by inclined planes on each side, for the use of the waggons: the teaming is thus progressing on the upper and lower one at the same time. 800 to 1000 cubic yards is said to be the utmost that can be excavated and led to embankment, or teamed, in one day, under ordinary circumstances; although this amount has been exceeded upon some occasions: thus, 1,600 have been moved per day at a steep cutting, on the Manchester and Leeds Railway, and that for many weeks together. The waggons hold about 2 cubic yards: 2½ or 3 yards is the utmost they can hold, even by piling up.

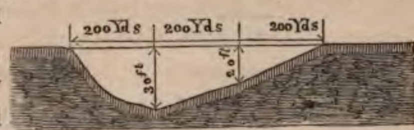
The most rapid method of executing earthwork on railways, and the like, is by throwing a part of the excavation to spoil, taking it out from the higher side all throughout the length, by means of barrows worked by horse gins, instead of removing it from the ends, the embankments being constructed from side cuttings; this, of course, forms the most expensive process of procedure, although land may sometimes be found suitable for it, which is termed *sideling ground*. The prices of earthwork vary according to the nature of the soil, locality, and extent of the work; the price with an average material may be stated at 9d. per cubic yard, which includes excavating, and teaming a distance of 1 mile to the embankment; with a lead of about 2 miles, it is about 11d.; and 3 miles 1s. 1d. When the lead exceeds 1½ miles, a locomotive may be advantageously substituted for horses in the teaming.

It is generally desirable to lay down the cuttings and embankments on a line of railway, canal, &c., equal or similar in cubic

contents. There are about 16,000,000 cubic yards of excavation upon the London and Birmingham Railway, $\frac{9}{10}$ths of which are used for the embankments, and $\frac{1}{10}$th laid as spoil banks, or spread over the country.

The amount of earthwork of an engineering undertaking is obtained from the section, the height of the embankment and depth of the cuttings being marked thereon; and the contents are calculated on the supposition, that "the area of any cross section in sideling ground does not differ from the area of a similar section on level ground;" therefore the section, being taken along the centre of the line, affords a true criterion of it.

The contents are usually found, by Mr. Macneill's tables, which he calculated upon the prismoidal formula, viz., "that the cubic contents of a solid figure (such as an embankment) is equal to the areas of each end added to four times the mean area, and the sum multiplied by the length of the prismoidal divided by 6," thus: suppose the number of cubic yards in the embankment, represented in the cut, were required (and the cuttings are obtained in a similar manner), enter the dimensions in the book, thus:



Longitudinal Section of Embankment.

Transverse Section of Embankment.

Base 30 feet, slope 2½ to 1.

Height in feet.	Tabular numbers.	Distance in yards.	Contents.
0, 20	=23.46	× 200	=4692
20, 30	86.42	200	17284
30, 0	44.44	200	8888
			30864

Area of embankment 30864 cubic yards.

The column, headed "Tabular numbers," is that derived from the tables; but they may be calculated without them, as follows:—

Height of end 20 } multiplied
Slope . . . 2.5 } together.
100
40
50.0
Base 30 added
80.0
Multiplied by 20 height
Area of end = 1600.0

20 height of highest end
0 ditto of other
2) 20
Mean height 10
Slope 2.5 multiplied together
50
20
25.0
30 base added
55.0
Multiplied by 10 mean height
550. middle area
4
2200 = 4 times middle area
1600 = area of end
6) 3800 feet
3) 633.33
9) 211.11
23.456 yards
Distance 200. in yards
Area of A 4691.200 cubic yards

Height of lower end 20 feet: the area consequently same as last = 1600.

Height	30	30	height of highest end
Slope	2.5	20	ditto of lower ditto
	150	2) 50	
	60		
	75.0	25	mean height
Base	30	2.5	
	105.0	125	
	30	50	
Area of higher end	3150	62.5	
		30	base
		92.5	
		25	
		462.5	
		1550	
		2312.5	middle area
		4	
		9250.0	
		3150.0	area of higher end
		1600.0	ditto of lower ditto
		6) 14000	
		3) 2333.33	
		9) 777.77	
		86.418	
		200.	
	Area of B	17283.600	cubic yards

Height of end 30 feet: the area consequently the same as last = 3150.

```
       30
        0
      ---
   3) 30
      ---
       15 mean height
      2.5
      ---
       75
      30
      ---
     37.5
     30    base
     ----
     67.5
       15
    -----
    337.5
    675
    -----
   1012.5
        4
   ------
   4050.0
   3150
  -------
6) 7200
  -------
3) 1200
  -------
9) 400
  -------

     44.444
    200.
    -------
Area of C   8888.800 cubic yds.
```

Summary of Contents.

A ———	4691.200
B ———	17283.600
C ———	8888.800

Area of embankment 30863.600 cubic yds.

Eccentric, or Eccentric Wheel, a contrivance employed in mechanics, and in very general use, for working the valves of steam-engines, consisting of a wheel situated upon the main shaft, but fixed out of its centre; it is placed in a brass ring, which fits it loosely, and rods are connected with the ring, and secured to a lever at the other end; an alternating motion is, therefore, given to the rods as the eccentric wheel turns round with the shaft, by which the valves are opened and closed.

Edge Railway, a certain description of roadway, consisting of a succession of iron bars or girders, properly supported, upon which the peripheries of the carriage wheels revolve; a flange, projecting 1 inch, being formed on the inner edge of the wheels, to prevent their getting off the rails.

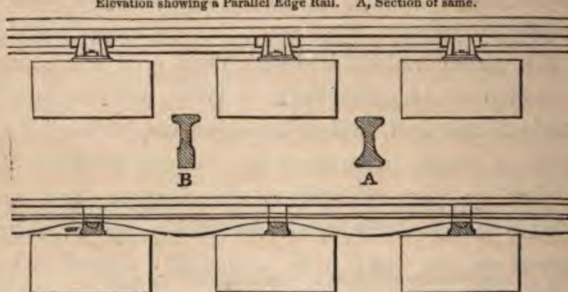
Edge-rails succeeded plate-rails, having been first used in 1785; the inconvenience arising from the dust laying on the latter probably led to their introduction originally, although the many other advantages possessed by them might not have been contemplated at the time, as the form of edge-rails is certainly very superior, combining the least expenditure of material with the greatest possible strength, and the friction upon them is less than upon tram-rails.

The first public railway laid with edge rails was constructed by Mr. Jessop, at Loughborough, in 1789; and they were originally made of cast-iron, in 3 or 4 feet lengths, with a flat base at each end, in which holes were left for the insertion of pins, by which they were secured to the sleepers, and cast-iron chairs were ultimately adopted for this purpose; they were also bowed on the under side, technically termed *fish-bellied*, which form edge-rails retained until very recently, the head being made about $2\frac{1}{2}$ inches wide, and rounded; a cross section taken through the centre of a rail showed a greater thickness of metal at the upper than at the lower part. The rails were after-

wards formed of wrought-iron, consisting at first of merely flat bars of iron, from 1 to 2 inches square, or bars 1 or 2 inches by 3 inches, which were found to damage the peripheries of the wheels of the carriages considerably, from their narrow shape and want of an upper table or head (neither case hardening the wheels, nor wrought-iron tires being invented at that time); and they continued to labour under this disadvantage until 1820, when Mr. Birkenshaw, of the Bedlington iron-works, invented a way of rolling and manufacturing iron rails of a fish-bellied form, and with heads complete, similar to the most approved cast-iron rails.

The increased velocity of the trains upon public railways have rendered wrought-iron rails absolutely necessary, and they are almost invariably employed at the present time. Cast-iron rails are also becoming less used every day upon private railways, as they are brittle, and apt to snap upon a sudden shock, and the wear is greater upon them, the interior of the rail not being so hard as the surface, arising from the more rapid cooling of the metal of the exterior: thus, when the surface of a cast-iron rail is worn through by the wheels of the carriages, the decay increases considerably. Wrought-iron rails can also be manufactured in longer lengths, by which a less number of joinings are required. The wear and tear of the surface of the rails upon the Liverpool and Manchester Railway, were stated by Mr. Dixon, the resident

Elevation showing a Parallel Edge Rail. A, Section of same.



Elevation showing a Fish-bellied Edge Rail. B, Section of same.

engineer, at $\frac{1}{10}$th of a ℔. per yard per annum; and it is remarkable, that good malleable rails do not oxydize when in use upon

a line of railway, although similar rails, thrown down at random by the side of the line, will lose weight continually.

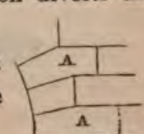
The rails originally laid down upon railways were very light, viz., about 35 lb. to the yard, but experience has shown the advantages of heavy rails: parallel rails, or rails having the top and bottom webs parallel, are almost universally adopted at the present time, in preference to the fish-bellied, although there are 10 miles of the latter on the London and Birmingham Railway; there are also 25 miles of 65 lb. parallel rails, and the remainder is laid with 75lb. parallel rails, the tables or webs being usually of similar size, and about 2¼ inches in width, and rounded off; and they are made in 15 feet lengths. The meeting of the several lengths of the rails in edge railways are usually formed with *butt joints*, or, in other words, with square joints, being the cheapest: half-lap joints are sometimes used, but diagonal joints may be considered the best. There are several descriptions of edge-rails in use, some of which may be found at different parts of this work. The side cut represents the "Croydon rail,"

which is screwed down on a timber beam, and therefore has a continuous bearing throughout.—*See Railway, Tram Railway, Chair, &c.*

Eduction Pipe (in steam engines), the pipe through which he steam escapes after fulfilling its duty.

Elbow, the name given to an abrupt turn in a river, frequently caused from the action of the current upon one of the banks, which thereby becomes washed away, when the silt is thrown to the other side, where it forms an *elbow*. They are usually remedied by erecting a rough stone dike across the concave side of the river, whereby the current is turned; or by a wing dam, as it is termed, built to the requisite height, which diverts the water into the proper course.

Elbow Joints, those voussoirs of an arch which form part of a horizontal course; as A, A, in the cut.



Embankment (sometimes termed *filling*), artificial banks, or mounds of earth.

Section of a Railway Embankment, a Culvert being shown beneath it.

The employment of embankments for the protection of low country from encroachments of the sea, and the overflowing of rivers, is of great antiquity, having been constructed by the Babylonians and Egyptians for the preservation of their cities, the which were mostly built on level plains; the water also afforded a means of irrigation, which the nature of the soil required; and the utility of embankments was not lost sight of by the Romans: but very little attention appears to have been bestowed upon them during the middle ages, in common with roads and canals, and their revival may be dated at about the same period as the latter. The embankments of the River Thames are supposed to be of great antiquity.

The embankment on any engineering work should be carried up with great care, and in regular concave layers; in other words, it should be gradually filled in towards the centre, which will give the sides an inclination to lean inwards and prevent their slipping: the water being properly run off, a high embankment is best formed by a succession of lifts, or stages, at least two in number, as the soil is more liable to slip when carried up to the intended height at once.

A large drain is required to be made at the top of all cuttings, on the high side of the ground, to cut off the land springs, and prevent the water running down the side slopes, and a smaller one is dug on the lower side, which should be continued along the foot of the embankment, communications being made from one side to the other under the latter, by means of culverts, as circumstances may direct. An embankment of moderate height, and formed of good materials, as chalk or gravel, will consolidate in about two or three years; but one formed of slippery clay, and of lofty proportions, will require ten years to elapse before it is thoroughly settled, up to which period wooden sleepers should be employed upon it, and the line may afterwards be relaid with stone blocks. The embankments of roads and approaches to bridges, &c., are sometimes formed with a layer of fagots, or brushwood, at the top, to receive the ballasting.—*See Earth-work, Dike, Slope and Slip.*

Engine, the name given to all machines and mechanical contrivances for producing, increasing, or regulating the power required for the accomplishment of any purpose. Most engines may be described as consisting of three parts: 1st, the starting power, by which the whole is put into motion, which bears no analogy whatever to the end attained, which is termed the *prime mover;* animal power, also water, steam, and even air, gas, and gunpowder, have been applied as prime movers; it would be represented in a steam-engine by the boiler and contingent works, by which the steam is produced. 2nd, That portion constituting what is commonly called the *engine,* and to which the ingenuity of man is most frequently directed: thus, steam may be the motive power in two different machines, but one may be a reciprocating, and the other shall be a rotatory engine. And 3rd, the machinery which absolutely performs the operation required, by which the object is attained, the motion being conveyed to it by that division of the engine last described: thus, in a steam-engine for pumping water, the pumping apparatus would represent it.

Mr. Murdoch, Mr. D. Gordon, and others, have made various experiments with highly compressed air, with a view of making

its power of expansion available, and using it as a prime mover instead of steam. Mr. M. I. Brunel also obtained a patent for certain mechanical arrangements for obtaining power from certain fluids, and for applying the same to various useful purposes, and he gave the preference to carbonic acid gas; but the high pressure at which his engine was obliged to work, viz., 30 atmospheres, formed a great difficulty, and he could not keep it sound and free from leakage. It has also been imagined by some, that electro-magnetism will some day compete with steam as a motive power.

Section of a Railway Excavation.

ENGINE-HOUSE, the house or shed erected over and about a steam-engine, which is constructed to suit the purposes of same.

ENROCKMENT, a term applied to the stone filling upon breakwaters, and the banks of rivers, underneath quays or harbours, &c. It consists of large masses of broken stones thrown in at random, and of sufficient size to resist the current.

ESTUARY, an arm of the sea.

EXCAVATION, a term referring to a cutting through the earth, when constructed on the surface. The method formerly adopted of forming an excavation, was by working at the face, and bringing the soil out in lifts, but it is not followed at the present time in extensive works, particularly where time is an object, the plan of running

a gullet through at once being mostly practised, and the soil is thrown down into the waggons from above: in removing the earth it is frequently dug out from beneath, when wedges and spikes are employed in *falling* it from above.

A line of railway, or canal, should be laid out in such a manner that the cubic contents of the cuttings should be of similar amount to the earth required for the embankments.—*See Earth-work* and *Embankment*.

EXPANSIVE ENGINE, a steam-engine in which the expansive power of the steam is taken advantage of and employed, instead of being dismissed at full power into the air or condenser, as the case may be. Mr. Watt availed himself of it, by cutting off the steam before the end of the stroke, which was finished by the power of expansion of the steam that was let into the cylinder. There are also engines in which two steam cylinders and pistons are employed, both of these being connected to the same beam; in one the steam works at full force, and is afterwards discharged into the other, which is of a larger size, where it acts a second time by its expansive force: this plan was first practised by Mr. Hornblower, and it succeeded very well; but the engine was rendered more complex and expensive. Mr. Woolf also employed the same plan, but with high pressure steam, together with a condenser; and engines of this description are yet used in some parts of the kingdom

FACE OF A STONE, that part of a stone forming the front or vertical face.

FACING (in hydraulic earth-work), a layer of common material or soil, laid over the lining or puddle, and upon the bottom and sloping sides of a canal or reservoir. The facing is useful at the period of execution, as it retains the puddle in its proper position during the working in; and it also affords a protection from the pole hooks of the bargemen after the works are completed.

FANNER, a contrivance of vanes or flat discs revolving round a centre for the purpose of creating a draught, by producing a

current of air. This principle has been applied to some locomotives in place of the blast-pipe; as to the "Novelty," by Messrs. Braithwaite and Erickson, which competed for the premium at the opening of the Liverpool and Manchester Railway, and to Mr. Hancock's patent road locomotive.

Falling Sluices, a certain description of flood-gates in connection with mill-dams, rivers, canals, &c., and which are self-acting, or contrived to fall down of themselves, in the event of a flood, whereby the water-way is enlarged.

Fathom, a measure of vertical distances, and employed in marine and mining operations, comprising a depth of 6 feet.

Feather-Edged, a term referring to any wrought substance, in which the work is materially reduced in thickness towards the edge.

Feeder (sometimes called a carriage or catch drain), a term applied to a small canal, cut, or channel, by which a stream or supply of water is conveyed for the use of a canal; feeders either convey the water into the reaches, or take it direct to the reservoir at the summit level, and are usually furnished with sluices and waste weirs, like ordinary canals.

Feed Pipe (of a steam-engine), the pipe employed for conveying the water to the boiler. The feed pipes of land engines are usually supplied by a cistern situated above the boiler, operating by the weight of the water, but in locomotive and other high pressure engines, the boiler is supplied by a force pump worked by the engine, and acting against the force of the steam.

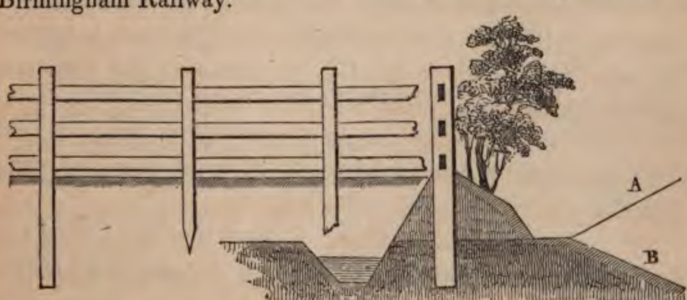
Feed Pump, the force pump employed in supplying the boilers of steam-engines with water.—*See Feed Pipe.*

Felloes, the covered pieces of wood forming the circumference of the wheel of a carriage, which is generally made in six or eight pieces, placed end to end, into which the spokes are inserted.—*See Wheels, &c.*

Felt, a fabric of hair and wool worked into a firm texture, and much employed upon railways; a piece of it is cut into the same shape as the seat of the chairs, and introduced between the

under side of the same and the upper surface of the blocks, to secure a firm hold, being previously well soaked in tar.

FENCING, a system of enclosure for the protection of roads, railways, and other works. The fencing upon railways should be situated upon the top of the mound formed from the excavation of the ditches, and the water collected in the latter should be properly diverted into the adjacent water-courses, and it should consist of good oak or larch posts, placed about 9 feet apart, and 3½ feet from the surface of the bank, with a scantling of 5 inches by 3½ inches, the posts which go below the ground being well charred; the rails should have a scantling of 3½ inches by 1½ inches or 2 inches, with a prick-post or stay, to support them between the posts, 5 feet long and 3 inches by 1½ inches; the joining of the rails and posts should be secured by iron hooping, some strong iron wires should be filled in next the ground in grazing lands, and quicks may be planted on the slopes of the mound. The total cost of fencing of this description will generally be about four or five shillings per running yard, including both sides of the line. Stone is also sometimes employed as fencing in localities where it is plentiful and adjacent to the line. The accompanying cut represents the fencing used on the London and Birmingham Railway.



Elevation. Section.
A, shows the slope when in Embankment. B, shows the slope when in Excavation.

FENDER, or FENDER PILES, the timbers placed in front of a quay wall, or other work, to protect it from injuries by vessels.—*See Quay.*

FERRY, the method commonly employed of crossing rivers previous to the general introduction of bridges; the sites of most of the river bridges of the present time were formerly occupied by ferries.

FIELD-BOOK (levelling).—*See Levelling.*

FIELD-BOOK (surveying).—*See Surveying.*

FILLING, or FILLING IN.—*See Embankment.*

FISHED BEAM, a beam bellying on the underside.

FIXED ENGINE (railway).—*See Stationary Engine.*

FLANCHE, or FLANGE, a projecting piece, or table, forming part of an iron girder or framework; the flanges of one casting are generally placed flat against those of another, and holes are drilled through each for the passage of bolts, whereby they are secured together.

FLANK WALLS, the wing or return walls of a bridge or lock.

FLASHES (upon navigable rivers), a description of sluice, erected for the purpose of raising the water over any shoals while craft are passing.

FLOAT, or WATER GAUGE, a body partially suspended and partly floating upon the surface of the water in steam boilers, being usually a piece of Yorkshire paving-stone; and employed to regulate the supply of water to the boiler by operating upon the valve at the top of the feed-pipe, and the water is kept at the same constant height through its agency. The height of water in the boilers of locomotives and marine engines, is ascertained by means of gauge-cocks and glass tubes, as floats will only act with stationary boilers. Gauge-cocks are also becoming much used for land engines.—*See Boiler.*

FLOAT-BOARDS, the boards fixed to undershot water-wheels to receive the falling stream, and to paddle-wheels, being the means whereby they act.

FLOATING BRIDGE, a certain description of steam-vessel, employed for ferrying passengers and goods across rivers, and the like.

The Torpoint Floating Bridge, by Mr. Rendell, is one of the

last built, and consists of a large flat-bottomed vessel, of a width nearly equal to its length, the engines being situated in the centre. Drawbridges are fixed at each end, by which carriages may be run on board by the horses, and the leaves are slightly raised during the passage, forming a sort of barrier. The bridge is guided by two chains laid across the bottom of the river, and secured upon each side to counterbalancing weights placed in deep wells, and they rise and fall according to the strain upon the chains, which are, therefore, never so tight as to interrupt the navigation, or so loose as to allow the bridge to make leeway and miss the landing-place: they also pass over guide-wheels fixed at each end of the vessel. The scheme has been found to answer well, there being two bridges employed at the same site, running alternately each for the space of one month.

Floating Clough, a moveable dam, or machine, used for scouring out channels or inlets. It is constructed of timber, and upon being floated to the required spot, is sunk, the flaps connected with it are then let down upon the banks on each side, an iron scraper being fixed thereto; its action is effected by the force of the tide, which pushes it along, when it clears away all obstructions in its course, and the action of the tide is afterwards employed to bring it up again.

Floating Harbour, a breakwater, composed of large masses of timber, anchored and chained together in certain positions, which rise and fall with the tide. The same principle has also been applied to the piers of marine erections.

Flood, or Tide-Gates, or Sluices, the gates employed in the admission of water from the sea or from a river, as the tide rises, &c.

Fly, or Fly Wheel, a heavy wheel employed in machines for equalizing the motion and increasing the effect, revolving upon an axle, after the same principle as a counterbalancing weight.

The fly-wheels of steam-engines are of large diameter, and are used to conduct the motion round the dead points, or such parts

where the crank has the least effect; and they are only suitable in stationary engines, on account of the inconvenience that would arise from their great size and weight: it is therefore customary, in motive engines, both those of land and of water, to employ two engines, or rather cylinders, as they are each supplied from the same boiler, and one piston is employed in full force while the other is passing the centre, whereby they mutually assist each other: thus, when

Fly Wheel.

one has finished its upward motion and is upon the turn downwards, the crank connected with it has a tendency to stick on the top, and just at that moment the crank of the other is in full play upwards, so that a continuous and nearly uniform motion is consequently attained; and engines so constructed are called *reciprocating engines,* the cylinders being placed in a vertical position in marine engines, and laid horizontally in modern locomotives. A rotatory engine is the only one that can give a uniform rotatory motion, as the course of the cranks in the former kind occasions an unequal motion, which may be readily perceived and sensibly felt, particularly in motive engines.

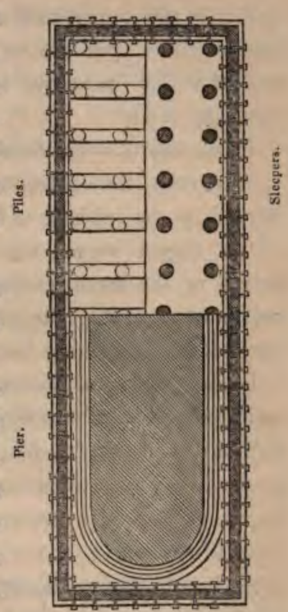
FOOTINGS (of walls), the projecting courses of stones or bricks at the bottom of all walls, which are laid for the purpose of resting the buildings firmly upon its base, and as a precaution against partial settling or sinking.

FORESHORE.—*See Breakwater.*

FOUNDATION, the superstructure upon which all erections rest, depending entirely upon the nature of the bottom, or subsoil. In the case of good firm ground, as rock, hard clay, or gravel, very little attention is required, except to rest the structure upon it square and regular throughout; when the soil is of a loose or yielding nature—as soft clay, common earth, or boggy earth—recourse must be had to artificial means of consolidating it. York land-

ings, also timber sleepers and planking, were formerly very generally employed for the foundations of large buildings, together with strong chain-bond laid in the footings of the walls; but concrete is the favourite expedient resorted to in the present day, upon which the footings are laid, and the walls carried up.

Plan.

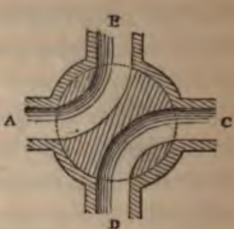


It is generally necessary to drive a row of sheep piles next the foundations of walls adjoining the sea, or rivers, and marshy soils, &c., to keep the water off, and prevent any lateral yielding of the soil below the foundations, the space between the piles being well puddled in; and in very marshy, or watery ground, the whole superstructure is obliged to be constructed on a timber platform, supported by piles and sleepers. The accompanying cut represents the foundation of one of the piers of Staines Bridge.

Section.

FOUR-WAY COCK (in steam-engines), a description of valve much used for passing the steam to the cylinder; it was invented by Leopold in about the year 1720. The accompanying sketch shows a vertical section of it. A, is the communication with the steam-pipe; B, the passage to the upper end of the cylinder; and C, that to the lower end: D being the passage to the condenser, or the escape into the air, as the case may be. By merely turning the plug or centre a quarter of a revolution, the action

is reversed, and the steam, instead of entering the lower part of the cylinder, will be on its passage to the upper one, and that last received into it will be escaping at D.



FREE-STONE.—*See Sandstone.*

FRICTION, the obstruction or resistance offered by the rubbing of the several parts of an engine or machine against each other, upon the application of the force necessary to put the same into action, by reason of which a great part of their power is lost, and the several parts of the machinery become worn and defective.

It arises from various causes, such as the roughness, inequality, or imperfection of the opposing surfaces, and from the interposition of dust, moisture, &c., between them; also from the action of gravity, and the adhesion of the several parts together: the degree of friction is also regulated by the amount of rubbing surfaces in contact.

As it is highly necessary to reduce the friction of engines to as small an amount as possible, they should therefore be constructed with as little rubbing surface as practicable, and oils or other unctious substances introduced between the parts in contact.

The resistance arising from the surface of roads has been considerably reduced of late years; the substitution of a rolling motion, as the motion of carriage wheels, for a sliding one, as that of a sledge, was found to reduce the friction very considerably at the period of its introduction; but the foremost plan for effecting the same is by means of iron railways, laid along a road prepared to receive them; tramways and pavedways may also be mentioned, and the many excellent common roads recently constructed throughout the kingdom; the carriages employed respectively upon each, have also received many important modifications.

The friction or resistance of the wheels of carriages arises, first, from the friction of *attrition*, or the pressure of the bearings upon the axles supporting them, as in roadway carriages, or that of the

axles against the bearings resting upon them, which support the carriage, as in railway carriages; and, secondly, from the *rolling friction*, or the resistance offered to the revolution of the wheels by the roadway, the amount of which depends principally upon the degree of smoothness and hardness of the surface over which the wheels are run; and the resistance of the road being so much reduced on railways, that presented by the axle of the carriage consequently forms by far the greater portion: it is, therefore, very important to keep up a constant supply of lubricating matter, in order to reduce it as much as possible, as before described. Oil unguents are best for light weights, a thicker composition being used for heavy machinery.

The resistance of a good level railway to the peripheries of the carriage wheels does not exceed 1000th part of the insistent weight, while upon common roads the average is about the 25th part of the same, or 40 times that of the railway; but the friction of the axle is much the same with both roadway and railway carriages, depending upon the degree of accuracy of the model.

The following shows the result of Mr. Macneill's experiments to determine the proportion of friction due to the road, and to the axles of roading carriages:—

Weight of waggon and load in pounds.	Power required to draw the waggon.	Resistance of the axles.	Resistance of the surface.
2240	31.0	13.0, 10.6 } 23.6	7.4
2800	52.0	16.2, 13.3 } 29.5	22.5
3360	70.0	19.5, 15.9 } 35.4	34.6
3920	91.0	2.7, 8.6 } 41.3	49.7

At an early stage of railroad communication, the chairs, or bearings resting upon the axles, were made very narrow, under an erroneous idea of reducing the friction, being only 1¼ inches in

length, and less than the diameter of the axles in breadth; but they are now made 3 inches long and upwards. Brass bearings present the least friction; but as they are usually formed narrower, nothing is gained in this respect by them. The bearings were also formerly situated upon the inner side of the wheels; but they are now placed on the outside, and the stage or frame-work of the waggon is elevated above the wheels, projecting beyond them on each side: the wheels are thus protected by the bearings, which are also made very strong; and, as the ends of the axles are not required to be as large in diameter as the middle portion, the friction is consequently reduced, compared with bearings on the inner side of the wheels—(an axle 3¼ inches diameter need not be above 2 inches on the outside of the wheels). The various improvements in carriages and carriage wheels have also tended to reduce the amount of friction.

Mr. Wood, after numerous experiments on the "friction of carriages," comes to the following conclusion, viz.:—

"That in practice we may consider the friction of carriages, moved along railways, as an uniform and constantly retarding force, both with respect to velocity and weight.

"That there is a certain area of bearing-surface compared with the insistent weight, and the friction is in strict ratio with that weight."

The area of bearing-surface in the axles of carriages, calculated to give the minimum of friction, he found to be 1 inch to every 98 lb. of the insistent weight. Mr. Peter Lecount, in his work on Railways, states, that this should not exceed 90 lb. per square inch, nor the length of bearing much less than twice the diameter of the axles.

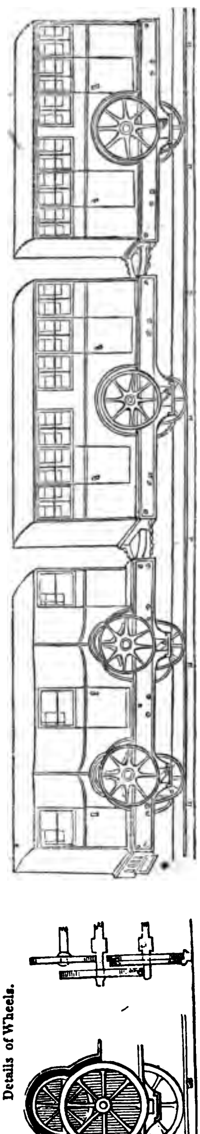
The total amount of friction upon a railway depends upon the weight of the carriages, or the weight contained within them, and is in the same proportion that the amount of rubbing action bears to the weight; and, taking all contingencies, it may be generally considered to average about $\frac{1}{250}$th part of the weight of the load, or 9 lb. per ton; *i. e.* a weight of 9 lb., hung over a pulley, will

draw one ton: thus a train, weighing 55 tons, will require a power of draught equal to 495 lb. to convey the same upon a level; but it varies according to circumstances. The friction is much increased where ropes, attached to a fixed engine, are used to conduct the trains, when it bears different proportions to the load, according to the diameter of the axles and peripheries of the running sheaves or friction-rollers on which the ropes runs. Mr. Walker, C. E., in his Report to the Directors of the Liverpool and Manchester Railway, in 1829, takes the friction of the ropes at $\frac{1}{22}$nd part of their weight; but it is considerably increased by bad weather. Messrs. R. Stephenson and J. Locke, in their reply to same, state it at $\frac{1}{12}$th.

The comparative resistance upon different descriptions of roads, may be classed as follows:—

	Per ton.		Part of the load.
On the best wrought-iron edge rails	$8\frac{1}{2}$ to 9 lb		$\frac{1}{264}$ to $\frac{1}{248}$
On common ditto, in bad repair . .	14		$\frac{1}{160}$
On the best cast-iron tram-rails, when newly laid down and swept clean . .	12		$\frac{1}{187}$
On common ditto, in a dusty state .	25		$\frac{1}{90}$
On the old wooden railways . .	30		$\frac{1}{75}$
On well made pavement . . .	33		$\frac{1}{68}$
On a broken stone road, upon a rough pavement bottom	46	*	$\frac{1}{49}$
On a broken stone surface upon a bottoming of concrete, formed of Parker's cement and gravel	46	*	$\frac{1}{49}$
On a broken stone surface, laid on an old flint road	65	*	$\frac{1}{35}$
On a gravel road	147	*	$\frac{1}{15}$

* These are according to Mr. Macneill's experiments; but the carriage employed not having been of good construction they may be taken at much less, particularly the friction of pavement: indeed it is questionable whether a pavedway, newly laid and swept clean, would amount to above half that stated.



Mr. Cole's Patent Anti-Friction Railway Carriages.

Details of Wheels. Elevation. Section.

It is singular that while the surface friction has been so much reduced, scarce any attempts have been made to reduce the friction of the axles of the carriages. Mr. Coles' patent anti-friction railway carriages certainly form an exception, and are worthy the consideration of the profession. The running wheels have anti-friction wheels bearing upon their axles, and these wheels again have smaller anti-friction wheels bearing upon them in a similar manner; the axles of the upper ones are fixed, and do not revolve with the wheels, but the middle and lower axles, with their boxes, or collars, work up and down in a groove of the framework of the carriage, and the whole weight of the load and frame is borne off by the upper friction wheels. Mr. Coles states, that they would reduce the friction at least $\frac{9}{10}$ths, and consequently effect an immense saving of propelling power, also wear and tear, and lubricating matter.

Friction Roller.—*See Sheave.*

Fuel (in reference to steam-engines), the material employed in converting water into steam. Those substances which receive and retain heat until wholly or partially consumed, are the most suitable for steam-engines, provided they emit neither smoke nor deleterious effluvia. Coal is the fuel mostly used for ordinary engines; but coke is generally employed in locomotives, at the present time, as it is particularly well adapted for them, it is preferable to coal in many respects; although the latter is yet

employed upon some of the colliery lines in the North of England, as the Leicester and Swanington Railway. Coke also packs well, and, being of a light substance, the air from the fire-grate passes through it freely; neither does any smoke arise from its combustion, which forms so great an objection with coal.

The coke used upon the London and Birmingham Railway is made upon the works, and consists nearly of pure carbon. The coke obtained from gas-works is objectionable, as it contains but a very small portion of carbon, and a considerable quantity of sulphur, which is very destructive to the metal of the boiler; coal also possesses the same injurious property, and this likewise forms a considerable objection with peat fuel: anthracite coal, or stone coal, although it is composed of nearly pure carbon, and produces neither flame nor smoke, is not well adapted for locomotives on account of its density, the draught of air through the fire-box being of the utmost importance to the power of the engine.—*See Locomotive-Engine and Steam-Engine.*

GABLE.—*See Roof.*

GALLERY, the term given to a certain description of underground excavation; thus coal-mines are worked in galleries or levels, and tunnels are sometimes worked by horizontal shafts, which are called *galleries* (the vertical being generally employed). A tunnel is projected through the cliffs at Dover, upon the South Eastern Railway, which is being formed by this method, and the galleries are intended to be left open for light and ventilation.

GASOMETER.—*See Gas-works.*

GAS-WORKS, the buildings in which gas is manufactured.

The introduction of coal gas for the lighting of towns and cities is of very modern date, although it is probable that the discovery was known for some considerable time previous. Mr. Murdock was the first who conceived the use of coal gas as a means of affording light by night; and he accordingly fitted up his house and offices, at Redruth, Cornwall, with it, in the year

1792; and, subsequently, his residence in Ayrshire: he also partially lighted the manufactory of Messrs. Boulton and Watt, near Birmingham, in the year 1798; and upon a public illumination, in 1802, it was exhibited at the *Soho,* and succeeded so well that public attention was drawn to the subject; and a company was formed, in 1804, for the purpose of manufacturing it, called the "National Light and Heat Company." Their first essay was made in Pall-mall, in the year 1807; which was for some years the only street lighted with it. But while gas was struggling with public prejudice in the metropolis, it was making great way in the provinces; and at length, in consequence of the success attending it, the old oil lights became abolished as public lights throughout most parts of the kingdom.

The manufacture of gas is conducted in large buildings erected for that purpose: the coal from which the gas is to be obtained being placed in iron vessels, termed *retorts,* of which a great number are employed; and a large building is appropriated for them, called the *retort house.* The retorts are usually of a shape, thus—  Cylindrical retorts were originally used, and are at the present time in some manufactories; they are laid horizontally in ovens, in groups of 5, 6, or 7 together, the furnaces being placed beneath; the mouth of each projects out from the oven, and a cover is screwed over it, air-tight, after the introduction of the coals: the gas is conducted by pipes from the retorts to the hydraulic main situated above them; the latter is also placed horizontally, and is generally half-full of the tar and water evacuated from the gas: the pipes from the retorts dip a few inches into the tar, by which all return of gas is cut off; the gas then passes through condensers, which consists of a quantity of iron tubes, placed vertically and bent in a serpentine form, and at the lower part of each turn syphon-pipes are fixed, by which the deposited matter is drawn off: these pipes are sometimes placed in cold water to cause a more rapid evacuation, whence the name *condenser* was given to them. Upon the gas being cleansed from all palpable and visible impurities, those of a more latent nature

have to be removed, viz. the sulphureted hydrogen, which is produced from the sulphureous substances contained in the coal, which is of a most injurious nature; this is effected by the interposition of lime, which possesses the property of abstracting it from such a combination, and it is performed in vessels termed *purifiers*, in which there is a quantity of lime mixed with water, to a sort of semifluid state, through which the gas is driven, and thence passes out, thoroughly purified; the lime is kept in a proper state of mixture, and prevented settling by an agitator, of somewhat the shape of a roller, placed horizontally and kept turning round by a steam-engine, or other power: and several purifiers are employed, through all of which the gas passes in succession. The renewal of lime takes place continually, as a certain quantity of lime will only purify a certain quantity of gas; the gas from common coal requires a quantity of lime equal in weight to $\frac{1}{10}$th that of the coal from which it is produced, and with the best coal $\frac{1}{3}$rd of the quantity is sufficient.

The gas is from thence passed into a large vessel, termed a *gasometer*, from whence the main pipes are supplied; it is of a cylindrical form, covered at the top and open at the bottom, and is placed in a pit, or tank, filled with water; friction-rollers are fixed upon the top edge, upon the inner sides of which the gasometer slides up and down, being suspended by a chain fixed at the top, where a pulley is situated; the chain then passes over another pulley at the side, and the lower end is attached to a weight. These chains are unnecessary in large gasometers, as their weight is not increased in the same proportion as their capacities; thus a large gasometer will remain suspended of itself; if very large, it will require a weight to keep it down. There are two pipes at the bottom of the tank, through one of which the gas enters, and through the other departs, for the supply of the main pipes. There are gasometers capable of holding the immense quantity of 60,000 cubic feet of gas; and there are sometimes as many as twenty of them connected with a gas-work. Upon the gas being turned on into the pipe for the supply of the

city, the gasometer begins to sink, and the pressure exerted is felt at the same moment throughout an extent of many miles.

It is customary, in most works, to measure the gas as it passes into the gasometer, which is effected by a very ingenious instrument, termed a *meter*. The flow of gas in the pipes is required to be steady and regular, and proportioned to the number of lamps burning; and accordingly as that number is increased or diminished at certain times of the night, so must the supply be adapted. There are men employed at the works during the night to regulate it, and who are informed of the state of the consumption, by pressure gauges connected with the main. A self-regulator, called a *governor*, is employed at some establishments for a similar purpose.

The pipes are of various sizes, and are formed of cast-iron, and generally made with a socket at one end only, the small end of one pipe being inserted into the socket end of another, and the joints are finished by molten lead. The mains connected with the gasometers are about 18 inches diameter, the pipes are laid as nearly straight as circumstances will admit of, with a slight fall, and all deposits are collected from time to time, and removed. A pipe, 1 inch in diameter, affords a light equal to 100 mould candles of six to the pound.

A gas obtained from oil has also been employed for the purpose of lighting towns, &c., which affords a stronger light than coal gas, but it is considered more expensive, and therefore not much used; the necessary process, however, is much less complicated.

Gates (of locks and sluices).— *See Lock-gates.*

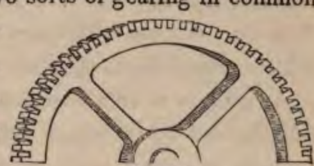
Gauge-Cocks, the cocks usually connected with the boilers of steam-engines, for the purpose of ascertaining the height of water in the boilers, and which are always used with motive-engines: glass tubes are also sometimes employed for the same purpose, and floats are commonly used for regulating the supply of water to the boilers of fixed engines.

Gauge of Way (as applied to railways), the width in the clear between the top flanches or rounded rims of the rails. It is very

necessary, in the practical working of railways, to keep *standard iron gauges,* from which all those employed on the line should be made; viz., one of the width between the rails, and another of the space between them.

The gauge of way generally employed and that adopted on the London and Birmingham, Grand Junction, and other great lines of railway, is 4 feet 8½ inches; but it is made 7 feet on the Great Western. The Irish Railway Commissioners recommend 6 feet 2 inches; and some of the Scotch railways are laid at 5 feet 6 inches.

GEARING, a series of toothed wheels for conducting motions in machinery generally. There are two sorts of gearing in common use, viz. *spur* gear, and *bevelled* gear (sometimes called *conical wheels*). The former consists of teeth arranged round either the concave or convex surface of a cylinder, in the direction of radii from the centre of the wheel, and are of equal depth throughout; but in bevelled gear the teeth are placed upon the exterior periphery of a conical wheel, and convex towards the apex of the cone, in which direction they are gradually diminished.


Spur Gear.


Bevelled Gear.

GIBS, pieces of iron used in connection with keys.—*See Key, Cottar, or Cottrel.*

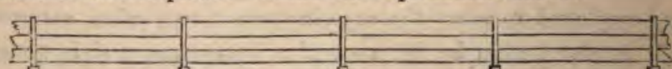
GIRDER, the name given to both timber and iron beams when resting upon walls or piers at each end, and employed for the purpose of supporting a superstructure or any superincumbent weight, as a wall, floor, or the roadway of a bridge, &c. A girder, employed to carry the superincumbent part of an external wall, is also known by the name of a *bressummer,* and is generally rested upon oak posts.

When a beam is loaded beyond its proper limits, it continually yields to the load, although slowly, until at length it breaks; and if the load approaches very near to the breaking weight, the time occupied will not be very considerable. Buffon states, that a beam should not be loaded with more than $\frac{1}{3}$rd of the weight which would be required to break it. The strength of beams is as the square of their depths, as proved by some experiments by Mr. Fairburn, who placed three cast-iron beams, of No. 2, Carron iron, upon supports, having bearings of 4 feet 6 inches; they were each 1 inch broad, and 1, 3, and 5 inches deep respectively, and which broke with 452 lb., 3,843 lb., and 10,050 lb. weight respectively, which is very nearly in the proportion of 1, 9, and 25. A girder will bear $3\frac{1}{2}$ times more weight when placed with the table downwards, as ⊥, than when it is placed upwards, thus, T.

As girders of sufficient scantling to span lengths of from 24 to 30 feet, and upwards, are difficult to be procured, it is customary to apply trusses to such, when they are called ***trussed girders.*** It is supposed by some engineers, that merely sawing a beam in two, lengthways, and bolting the pieces together in a different relative situation to what they were previously, adds much to its strength; in other cases wrought-iron truss bolts are placed between them, by which either iron or oak struts are made available to strengthen the beam, and prevent its ***sagging,*** or bending in the middle.—***See Cuts.***

Trussed Girder.

The term ***built beam*** is applied by some writers to a beam composed of several pieces—as the one represented below.

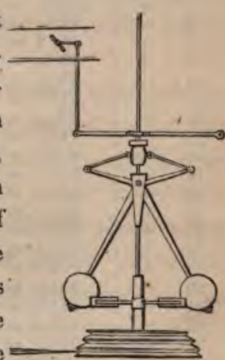


Built Beam.

GLAND, or COLLAR.—*See Collar.*

GNEISS.—*See Granite.*

GOVERNOR, or CONICAL PENDULUM, the contrivance connected with some machines for regulating their motion.



The Steam Governor.

The steam governor consists of an upright spindle, which is put in motion by the engine, and from which two balls are suspended by rods; these partake of the motion of the spindle, and the balls fly off from it, accordingly as it is rapid or slow, by reason of the centrifugal force, in consequence of which the upper portion of the contrivance is either elevated or depressed, which operates upon the throttle-valve, and regulates the supply of steam to the cylinders; thus, if the engine is going too fast, the governor checks it, by partly closing the throttle-valve; but if too slow they fall down, and allow more steam to pass.

The governor was first applied to the steam-engine by Mr. Watt, although it had been in use for other machines sometime previous; as to water-mills and wind-mills, the governors of which may be described generally as acting upon a similar principle.—*See Steam-Engine.*

GRADIENT, a term indicative of the proportionate ascent or descent of the several planes upon a railway; thus, an inclined plane, 4 miles long, with a total fall of 36 feet, is described as having a gradient of 1 in 586⅔rds, or 9 feet per mile. These slopes are also called by the general name of *gradients;* although the difference between a gradient and an inclined plane is not very clear; the former is, however, understood to allude to a slope of small inclination only, while the latter refers to a steep one.

Clivity is a more appropriate term than gradient, as suggested by Mr. Macneill; and its derivations, *acclivity* and *declivity*, are very comprehensive and significant.

The following Table of Gradients, by Mr. C. Bourne, C.E., may be found useful:—

Per Mile.				Per Chain.	Per Mile.				Per Chain.
1 ft.	=	1 in 5280	=	.15 of an in.	31 ft.	=	1 in 170.3	=	4.65 of an in.
2	=	„ 2640	=	.30 „	32	=	„ 165.0	=	4.80 „
3	=	„ 1760	=	.45 „	33	=	„ 160.0	=	4.95 „
4	=	„ 1320	=	.60 „	34	=	„ 155.3	=	5.10 „
5	=	„ 1056	=	.75 „	35	=	„ 150.8	=	5.25 „
6	=	„ 880	=	.90 „	36	=	„ 146.6	=	5.40 „
7	=	„ 754.2	=	1.05 „	37	=	„ 142.7	=	5.55 „
8	=	„ 660.0	=	1.20 „	38	=	„ 138.9	=	5.70 „
9	=	„ 586.6	=	1.35 „	39	=	„ 135.4	=	5.85 „
10	=	„ 528.0	=	1.50 „	40	=	„ 132.0	=	6.00 „
11	=	„ 480.0	=	1.65 „	41	=	„ 128.8	=	6.15 „
12	=	„ 440.0	=	1.80 „	42	=	„ 125.7	=	6.30 „
13	=	„ 406.1	=	1.95 „	43	=	„ 122.8	=	6.45 „
14	=	„ 377.1	=	2.10 „	44	=	„ 120.0	=	6.60 „
15	=	„ 352.0	=	2.25 „	45	=	„ 117.3	=	6.75 „
16	=	„ 330.0	=	2.40 „	46	=	„ 114.8	=	6.90 „
17	=	„ 310.6	=	2.55 „	47	=	„ 112.3	=	7.05 „
18	=	„ 293.3	=	2.70 „	48	=	„ 110.0	=	7.20 „
19	=	„ 277.9	=	2.85 „	49	=	„ 107.7	=	7.35 „
20	=	„ 264.0	=	3.00 „	50	=	„ 105.6	=	7.50 „
21	=	„ 251.4	=	3.15 „	51	=	„ 103.5	=	7.65 „
22	=	„ 240.0	=	3.30 „	52	=	„ 101.5	=	7.80 „
23	=	„ 229.5	=	3.45 „	53	=	„ 99.6	=	7.95 „
24	=	„ 220.0	=	3.60 „	54	=	„ 97.8	=	8.10 „
25	=	„ 211.2	=	3.75 „	55	=	„ 96.0	=	8.25 „
26	=	„ 203.1	=	3.90 „	56	=	„ 94.3	=	8.40 „
27	=	„ 195.5	=	4.05 „	57	=	„ 92.6	=	8.55 „
28	=	„ 188.6	=	4.20 „	58	=	„ 91.0	=	8.70 „
29	=	„ 182.1	=	4.35 „	59	=	„ 89.5	=	8.85 „
30	=	„ 176.0	=	4.50 „	60	=	„ 88.0	=	9.00 „

GRANITE, a very hard durable silecious stone, and one much used for engineering purposes; the essential ingredients of which are felspar, quartz, and mica, which are scattered irregularly throughout it: gneiss is composed of similar particles, but disposed in beds. Grey granite is more generally employed than red, on account of the difficulty of working the latter, from its excessive hardness. Aberdeen granite is considered superior to that of Cornwall, as it abounds more with quartz; the latter has more felspar in its composition.

GRAVING DOCK.—*See Dock.*

GRAVITY (as applied to railways), a term referring to the extra weight acquired by a train of carriages when upon planes not perfectly level or horizontal; or, in other words, to the downward pressure, which force is in proportion to the clivity of the plane.

If the train is proceeding up the plane, great additional power is necessary to overcome the gravity compared with that required

upon the level portions of the line, particularly if the same degree of velocity is to be maintained. Upon a plane 1 in 50, the resistance by gravity is 44.80lb per ton; and upon 1 in 90 it is 24.83 lb. per ton, which, on a train of 60 tons gross, amounts to 1493 lb., and is sufficient force to propel a train amounting to 186 tons upon a level: if, on the contrary, the train is descending the plane, the gravity assists them.

It is customary to shut off the steam of an engine in descending steep planes, the gravity being sufficient to propel the train, and it is moreover checked by the brake accordingly as may be required.—*See Inclined Plane.*

Grillage, a term applied to the sleepers and cross beams supporting a platform, upon which some erections are carried up, as piers, in the case of marshy or watery soils, whereby an equal bearing is given to the foundation. In the event of clay being employed as a grillage, instead of timber, it should be 4 or 5 feet in substance, and spread in layers, and well rammed in between the heads of the piles.

Groin, a frame-work usually of wood, and constructed across a beach between high and low water-mark, and perpendicular to the general line of same, for the purpose of retaining the shingle already accumulated on the spot, or to obtain more from the sea: they usually consist of piles and planking, land-ties, &c.

Groined Arch, an arch cutting across another arch in a transverse direction; the point of juncture being termed a *groin.* It has been said that the groined arch is the most stable of all arches, and, therefore, capable of being executed with a very small rise, provided the abutments are sufficiently strong to support it; yet groined arches are but seldom used in modern works, whilst the cylindrical appear to have been carried almost to as great an extent as practicable.—*See Arch.*

Grouting, a description of mortar used in brick and stonework, composed of quick lime and a portion of fine sand, employed in a thin liquid state; it is poured into the upper beds and internal joints of the work.

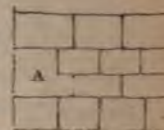
Brickwork should be well grouted every four courses.

GUDGEON, the term applied to the extremity of a horizontal shaft or axle, when it turns in a collar. It is customary to make the gudgeons of smaller diameter than the other portions of the shaft, for the purpose of reducing the friction as much as possible.

GULLIES, a term sometimes applied to iron tram-plates or rails.

GUTTER, a trough for carrying off the water from any works. The trenches dug for the reception of puddling are also termed *gutters*, which are usually formed about 2 or 3 feet in thickness, and wider at the bottom than at the top.—*See Canal*.

HACKING (in walling), an objectionable plan, practised by workmen, when one of the courses of a wall cannot be carried up of equal depth throughout its length for the want of stones sufficiently large for same. The hacking consists in dividing the remaining portion into two courses; the end stones (A, in cut), being frequently notched to receive the stones of the lesser courses.



HALF-TIDE DOCK, a basin connecting two or more docks, and communicating with the entrance basin.

HARBOUR, or HAVEN, the name applied generally, to a port, or to the entrance of a port, where vessels may lay at anchor, sheltered from storms.

It is highly necessary that harbours should possess a good entrance, consisting of firm ground, free from rocks, so that a ship may not be liable to founder, also of width and depth of water sufficient to float the largest vessels; if surrounded by lofty hills and mountains, it is an advantage, as they are then screened from the effects of high winds, and when their situation is far inland, they are secure of bombardment from the sea.

The entrances to some ports are formed with good harbours naturally, but artificial means are obliged to be resorted to, in some cases, to render them safe, by enclosing a certain space from the sea, in such a manner as to form a shelter to the shipping. The works consist of two curved arms, called *piers* or *jetties*, which are built in a suitable position to counteract the peculiar local effects of the

winds, and afford a free ingress and egress to vessels at the mouth. They are also sometimes formed by the building of isolated walls, called *breakwaters,* instead of jetties, and likewise by the fixture of large masses of floating timbers, called *floating breakwaters,* which rise and fall with the tide.

Harbours are generally furnished with a lighthouse, to direct ships at night, also with numerous buoys, moorings, posts, &c.

A backwater, or scouring power, is usually connected with the entrance of a harbour, and which should be so situated that the force may act in the direction of the tidal wave, forming a small angle with it, and it should on no account approach a right angle, which has the effect of impeding the shingle, as may be frequently observed, when a bar is soon formed; and, by the same rule, the mouth of a river, crossing a tide wave at right angles, will also cause a bar; this principle of action, therefore, should not be overlooked in the construction of harbours and sea embankments: and it may be further remarked, that in carrying the necessary works into execution, the commencement should never be opposed to the tidal wave, but if possible run in the same direction; and the greatest care should be taken that the motion of the shingle be not opposed, but rather diverted, as depositions of it are sure to occur unless efficient remedies are adopted. Shingle has been known to acquire an extent of area equal to nearly 20 square miles in the course of two years, the same being from 5 to 8 feet deep, even where there has been a powerful stream of backwater. A close investigation of local circumstances is of the utmost importance, previous to determining the precise site of a harbour —comprising the peculiar features of the coast, the effect and general action of the tides, and nature of the deposits—since the erection of piers and other works must influence the movements of the shingle on the beach in some way.—*See Backwater and Isolated Harbour.*

HARD, a term signifying a ford or passable place in a river, or fen, consisting of a hard bottom of gravel, which is supposed, in some cases, to have been brought there for the purpose of forming

a passage across: they are not often met with now, having been removed on account of their impeding the navigation in dry seasons, and increasing the floods in wet ones.

HATCH.—*See Lock Gates.*

HEAD OF WATER, a term signifying a regular height of water in any stream or basin, and intended for the supply of mills, fountains, and the like: they are usually supported by banks of earth, in a similar manner to dams.

HEADING.—*See Drift.*

HEADING COURSE (in masonry and brickwork), a course consisting of all headers, or stones, bricks, or the like, laid lengthways across the whole thickness of a wall.—*See **Bond and Stretching Course.***

HEADWAY, a name sometimes applied to the clear height under the arches of bridges, tunnels, &c.—*See **Arch.***

HEDGEHOG, a machine for removing mud, silt, &c., from rivers and streams.

It is in shape somewhat similar to a road or garden roller, consisting of a wheel revolving on an axle, to which drawing shafts are fixed. Timber stocks are projected from the cylinder with iron spades bolted thereto, which act upon the bottom of the river, clearing away all obstructions.

It is generally attached to the stern of a barge which is drawn by horses; sometimes the barge is moored, and the machine moved backwards and forwards by means of leading blocks and chains; mechanical purchase being obtained by means of the barge.

HEWN STONE, a term applied to stone when reduced to the required form, by means of a mallet and chisel only.

HIGH-PRESSURE, or NON-CONDENSING ENGINE, an engine in which the cylinders are worked by the elastic force of the steam alone, without the aid of a vacuum—it is consequently of very great power; and the engine is also light, compact, and cheap, compared with others, from the circumstance of the whole of the condensing apparatus being dispensed with. The loco-

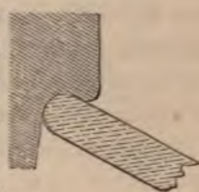
motive engines in general use are all constructed upon this principle.

From the circumstance of the steam of non-condensing engines being of such very high pressure, and their great evaporating surface, the fire is required to be kept at a greater heat than usual with other engines; the repairs, therefore, become exceedingly heavy, and their durability comparatively short in comparison with the latter.—*See Steam-Engine and Locomotive Engine.*

HIP.—*See Roof.*

HOARDING, the name given to the wooden boarding enclosing any building operations.

HOLLOW QUOIN (in lock-gates), the recess made in the walls of locks at each end for receiving the gates, which are properly hollowed out to fit the shape of the quoin-posts.—*See Lock-Gates.*



HORSE PATH, or TRACK, the name sometimes given to the towing-path by the side of a canal, or river, where horses are used for towing; they were formerly made only on one side of canals, but are now frequently on both, and about 8 or 10 feet wide.

HORSE POWER, the power or force which a horse generally exerts, which is compounded of his weight and muscular strength; the weaker and heavier horse will overcome a resistance which the stronger and lighter horse cannot, provided the excess of his weight exceed, in the smallest degree, his deficiency in strength. A horse drawing in a mill, or machine of any kind, should be allowed a track of sufficient diameter to exert his power to the greatest advantage; it ought not to be less than 40 feet for full-sized horses; and where such an extent cannot be obtained, horses of reduced size should be employed, in order to correspond with the contraction of the track: it has been ascertained that a horse loses $\frac{2}{3}$rds of his effective strength when removed from a 40 feet track-circle to one of 19 feet; and a horse works to the greatest advantage when the line of draught inclines a

little upward to his breast, making a small angle to the horizontal plane.

The amount of force exerted by a horse is generally reckoned, in mechanical calculations, equal to 33,000lb., raised 1 foot high per minute; and if continued throughout the whole day of 8 hours, amounts to 150lb. conveyed a distance of 20 miles, at a speed of 2½ miles an hour: but some engineers consider 125lb. a sufficient load for an ordinary horse, although, according to Mr. Bevan's calculations (deduced from the effects produced by horses in several different ploughing matches) 160lb., raised at a velocity of 2½ miles per hour, is the average of their power; but much depends upon the size and muscular strength of the horses employed, and the mode of shoeing, fitting of the collar, line of draught, and other circumstances.

The power of horses decreases with the velocity of their speed: thus, taking 125lb., moved twenty miles a day, at a rate of 2½ miles an hour, or 2,500lb., conveyed 1 mile, as the daily performance of a horse (which is the power assigned to a horse by Mr. Nicholas Wood), and allowing for the friction of railway carriages at 8½lb. per ton, gives nearly 300 tons, conveyed 1 mile, as the power of a horse upon a railway. And as the friction of a stage upon a turnpike road, when loaded, amounts to 83lb. per ton (according to Mr. Macneill's experiments), and calculating it to weigh 2 tons, would give 42lb. as the share of each of the 4 horses, the rate of travelling being about 10 miles an hour; and supposing they average 13 miles per day, which is taking the utmost, the total force exerted by each horse, per day, is equal to 546lb., conveyed 1 mile: now, applying this force upon a railway, as in the former instance, reckoning the friction again at 8½lb. per ton, gives 64 tons moved 1 mile; their relative efforts at 2½ miles, and 10 miles, an hour, are, therefore, in the proportion of 300 to 64.

The belief that locomotives will one day compete with horses upon common roads is becoming very general in the scientific world: how far this is correct time will show; but the superiority

of locomotives over horses, upon railways, is very evident : yet as it is necessary that the trains upon a railway should start at certain fixed periods, whether they have full loads or not, they consequently become expensive with light ones.

The following Table shows the comparative expense of locomotives and horses as a motive power upon railways :—

HORSES.			LOCOMOTIVE ENGINE.		
Rate of speed, in miles per hour.	Cost of haulage, per ton per mile.	Charges of conveying goods and passengers.	Rate of speed, in miles per hour.	Cost of haulage, per ton per mile.	Charges of conveying goods and passengers.
	d.	*d.*		*d.*	*d.*
$2\frac{1}{2}$	0.56	1.65 per ton per mile.	8	0.375	1.065 per ton per mile.
4	0.9	3.627 per ton per mile.	12	0.5	3.5 per ton per mile.
10	$\frac{1}{4}$*d.* per passenger.	1*d.* to $1\frac{1}{2}$ per passenger.	20	0.25 per passenger.	1*d.* to $1\frac{1}{2}$*d.* per passenger.
10	2.24 per ton per mile.	1*s.* 3*d.* per ton per mile.	20	0.73 per ton per mile.	12.37 per ton per mile.

The expense of conveying goods by horses, at $2\frac{1}{2}$ miles an hour, is about the same as by locomotives at 12 miles, therefore, where speed is of no consequence, horses may be preferred ; as a horse railway can be executed for a much less sum than a locomotive line. There are many railways, in the North of England, where horses still continue to be used.—*See Canal.*

Horse Run (in earthwork), a contrivance for drawing up the loaded wheelbarrows from the bottom of deep cuttings for railways, docks, &c., by the assistance of a horse, which walks to and fro, instead of round, as in a horse gin. The horse runs, employed at the deep chalk cutting at Tring, on the London and Birmingham Railway, were worked by two horses, the which pulled a loaded wheelbarrow from the bottom, a man guiding it up the plank by means of the handles ; and, in descending, he

merely attached the rope to the barrow, and the friction of the tackle offered sufficient resistance to let him down the plank with safety.

Horsing Block, a square timber framing, used in forming excavations for raising the ends of the wheeling planks.

Hub, a block of wood employed to stop the wheels of carriages, and prevent their progress by gravity, or any acquired momentum: they are used upon railways with great advantage.

Hurries, a term sometimes applied to a timber framing, or stage, erected on the quays of harbours, and navigable rivers, and at the extremity of railways connected with coal-pits, spouts being fixed at the end of the hurries, down which the coals are discharged and shot at once into the hold of the ships.

Hydraulic Engine, the term applied to all machines which receive motion from the weight or impulse of water, and to engines employed in raising water, &c.

The term, however, bears more immediate reference to a machine, somewhat resembling the steam-engine, in which the piston is impelled by a column or head of water, instead of by the force of steam.—*See Pump, Water-wheel, &c.*

Hydraulic, or Water Lime, lime which possesses the property of hardening, when used in water operations. A small mixture of burnt clay, with the lime, during the process of burning, will give it this quality; also brick, or tile dust, or pozzolano, the latter being very valuable for hydraulic works.

Ice-Boat.—A boat employed on canals to break the ice in frosty weather; it is usually heavily laden, and protected by iron bows and keel. The improved ice-boat, which forms an inclined plane under the ice, and rents it upwards instead of thrusting downwards, as in the ordinary boats, has been found very efficacious in practice. A man steers the ice-boat from the towing-path, by means of a long shaft attached to a pole projecting over the stern. Ice-boats are, however, only applicable when the ice is of but little thickness, or to clear it away after a thaw.

Inclined Plane, one of the mechanical powers or con-

trivances by which the raising of heavy bodies is much facilitated, as a plane inclined to the horizon sustains but a portion of the weight of any load that may be resting on it; thus, if the plane be 6 feet long, with a rise of 1 foot, and a load of 6 ℔. be placed upon it, and a cord passed from the same over a pulley at the top of the plane, and parallel thereto, then a weight of 1℔. fixed at this end will balance the load: if the height is 2 feet, 1℔. will balance 3℔.; but the *total amount* of power required to move a body up a hill is the same that is required to lift it up a height equal to the degree of altitude that it is moved up the hill; thus, the power to run a carriage, weighing 2 tons, a distance of 12 yards up a rise of 1 in 12, is similar to that which would be required to lift it up 1 yard.

The term is indicative of all planes not perfectly horizontal (of a higher level at one end than the other); but when applied to railways, it is generally understood to refer to steep inclinations only, as the Euston-square inclined plane, of 1 in 86, on the London and Birmingham Railway, and the Box inclined plane, of 1 in 107, on the Great Western Railway, at Bath.

Inclined planes should not have an uniform slope or clivity, but they should be laid with a greater fall at the higher than at the lower end, towards which it should gradually diminish. The velocity acquired at commencing the descent will thereby be counterbalanced by the gravity increasing as the carriages approach the extremity of the plane.—*See Steam and Self-acting Inclined Plane.*

Injection Engines, those steam-engines in which the steam is condensed by an injection of cold water into the cylinder, as most condensing engines at present in use. Mr. Samuel Hall's patent engines effect the condensation without any injection, which system is considered to be the most perfect; the presence of air into the condenser is also prevented by it.

Inlet, a term applied to an opening into a drain or culvert.

Intermediate Space, the centre space or distance between each line of rails, on double lines of railway, which varies on different lines. It is frequently made the same as the width

between the rails, or 4 feet $8\frac{1}{2}$ inches; although it is increased to 6 feet on the London and Birmingham and other Railways.—*See Railway, &c.*

INVERT, or INVERTED ARCH, a term applied to an arch when placed in an inverted position, the intradoes or soffit of the arch being below the axis or springing-line; they are much employed in the foundations of buildings, and are turned between piers and the like, to connect the whole together, whereby the bearing of the foundations is rendered regular and even throughout: they are also used for the purpose of excluding water.

IRON, a very hard and durable metal of a bluish white colour, very malleable and elastic.

Iron is considered to be the most important of the mineral treasures of the United Kingdom after coal; but it is not often found in a natural state, as the ore is generally diffused in immense beds, and is converted, by chemical means, into pure metal.

Sweedish and Russian iron have long been held in high estimation on account of their being smelted by charcoal furnaces. Pit coal is obliged to be used in this country for that purpose, owing to the scarcity of wood (the period of its first application was in the year 1619): notwithstanding, the best English chain cable iron is very little inferior to foreign iron.

Iron is of two kinds, viz., the *cast*, or moulded, and the *wrought*, or forged; the latter is employed for all purposes where strength and stiffness to resist a pull or strain laterally is principally required: cast-iron, on the contrary, is mostly used in a vertical position, and is not to be depended upon as a tie, unless cast of very large proportions; it is also much used for engineering purposes, in such situations where it would be difficult to apply wrought iron, as for the ribs of bridges, &c.; also for ornamental purposes, arising from the facilities which it presents, being capable of taking almost any shape.

The manufacture of iron received a vast impulse at the period of Watt's great improvements in the steam-engine, on account of the increased demand thereby occasioned: this new power was also employed in improving the blast in the furnace.

There is nothing particular to distinguish common iron ore from common stone, excepting its greater weight; and it is worthy of remark, that the fuel required for its reduction generally accompanies it; the ore is principally found in coal measures, and in connection with limestone, both of which are used in the operation. The metal is obtained from the ore, by a process termed *smelting*. It is first broken into moderate-sized pieces, and roasted, or baked by a method very similar to the burning of bricks by clumps, being formed into heaps about 30 feet long, 15 feet broad, and 5 feet high, with sloping tops: a thick layer of coal is placed at the bottom, and intervening layers are also laid within; the whole is then ignited, and left to burn for four or five days, and when cool, the ore is taken to the smelting furnace, which is a brick or stone building, in the form of a tower, from 40 to 50 feet high: it is filled with ore, and a mixture of coke and limestone, in the proportions of about 3 of ore to 4 of coke, and 1 of limestone.

The accompanying sketch represents a blast furnace upon the most simple and approved principle. The interior portion, marked A, is built of fire-bricks; it is fed at the top, through the hole B; the fire, situated at the bottom is forced in by the powerful aid of the blast-pipe, which is worked by a steam-engine; an opening is left at the bottom, for the escape of the metal into a receiver, C, upon its acquiring a state of fusion; and it is conducted into sand-moulds, laid upon the ground, of the pattern required, or into furrows made in sand: the large mass, which sets in the main one, being called by the workmen a *sow*, and the lesser ones, *pigs*—this sort being known by the general name of *pig*, or *crude* iron. The furnace is never allowed to cool, but fresh ore is continually poured in at the top, as may be found necessary; in the event of repairs being

required, it is blown out: the coke not only serves as fuel, but it attracts the oxygen from the ore, and enters into combination with the iron in a state of pure carbon: the limestone assists the smelting as a flux upon the earths in connection with the ore, as flint and clay; the which rise and float upon the surface, and are termed *scoria*, or *slag*.

The hot air blast is now used in preference to the cold air blast, as a great saving is effected by it; a large portion of the heat being absorbed by the cold air, which occasions an unnecessary consumption of fuel: coal has also been successfully employed in some instances, in place of coke.

Wrought iron is prepared from the cast, the pigs being again subjected to the furnace, melted, and run into moulds, by which the remaining extraneous matter, as earth and oxydized iron, is got rid of; this process being repeated until the iron clots together upon being stirred, forming soft pasty lumps, when it is taken out and beaten by the large forge hammer, which is worked by a steam-engine; and when the metal is compressed into cakes of about 1 inch in thickness, they are placed in another furnace, and softened and shaped into bars, the ends being welded together; and the operation is completed by the entire bars being again placed in the furnace, softened, and beat under the forge hammer: by this process, the metal is freed from all carbon, oxygen, and earthy ingredients; and instead of being brittle and easily fusible, it is now possessed of great tenacity, ductility, and malleability.

Iron Bridge, a description of bridge formed of cast iron, and employed in situations where the width or span is very great, compared with the rise; being preferable, in such cases, to those of stone.

Iron bridges consist, generally, of ribs thrown across, having iron plates filled in between them, as described under the general head of "Bridge."

The first iron bridge was constructed in the year 1779, and erected over the Severn, a little below Colebrook Dale, at a part of the rivêr where the stream was narrow, and, consequently,

rapid: the span of the ribs is 100 feet 6 inches, the spandrels being filled in with metal rings; but owing to the piers not having been sunk sufficiently deep to ensure a firm foundation, nor strong enough to resist the internal pressure of the ground, which was of a slipping nature, the masonry became thrown out of the perpendicular, and, consequently, much damaged; and the form of the ribs being nearly semi-circular, they did not offer much resistance to this pressure; whereas, had they been segments, their power of withstanding it would have been much greater. The success of this experiment was, however, fully acknowledged and appreciated, although the ribs are now mostly executed in flat segments.—*See Bridge.*

Irrigation of Land, the operation of applying water to land, for the purpose of agriculture.

Irrigation is a process but little practised in this country, owing to the soil not requiring it; although it generally forms a part of the system of drainage in low lands, the requisite works for enclosing the water serving the purposes of both; and by storing it up in dry seasons, the sluices have only to be opened to flood the whole of the lower level.—*See Drainage for Agricultural Purposes.*

The irrigation of land may be described, generally, as being of three kinds; first, simple flooding, usually termed flooding and warping; secondly, surface irrigation; and, thirdly, subterraneous irrigation. The first has long been practised, being an evident imitation of nature in the overflowing of rivers; it consists in the floating of a quantity of water over the land, and is generally practised with grass land; and when it is charged with soil, or any alluvial matter, it is called *flooding and warping;* the warp is very serviceable, and increases the fertility of the land considerably; it also tends to raise the surface of the soil. The second description, or *surface irrigation,* is executed by open cuts or channels traversing the surface of the land, by which the water is conveyed to the roots of the grass. This system, also, is of great antiquity, and, being simple, it has continued in use up to

the present period. The meadows around Salisbury have been watered in this way from time immemorial, where these numerous cuts also assist the drainage, there being much water in the neighbourhood. The third kind, or *subterraneous irrigation*, is of more modern date, and constitutes the most approved plan, being more convenient, and requiring the least quantity of water of any. It is effected by a system of main drains, having covered gutters connected with them, and placed in the sub-soil, the former communicating with a main conduit, or *feeder*, proper sluices being attached, by which the water is discharged when required.

Irrigation by Liquid Manure is a subject well deserving the attention of the profession, no practical plan of effecting the same having yet been devised, although it is much adopted on the Continent, and there are occasional instances of it in this country, as in the neighbourhood of Edinburgh, where it is employed on grass land, and succeeds exceedingly well.

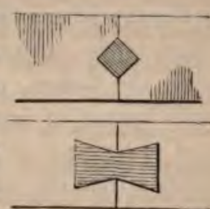
Isolated Harbour, a harbour of refuge, built independent of the coast, and connected to it by a bridge, under which the shingle is allowed to pass; the inclination of the shingle to travel onwards, even through a very contracted channel, gave the idea of this plan of construction; and by keeping the mouth of the harbour in sufficiently deep water, no cause will operate to diminish the depth, impede the silt, or stop it up.

The above is a plan of an isolated harbour upon the system of Mr. William Tait, C. E., who has devoted considerable attention to the possibility and expediency of constructing them; the arrow

represent the direction of the tidal current and the dotted line, the course of the prevailing south-west wind.

JIB, the projecting frame of a crane, from which the weight or goods are suspended.

JOGGLE, a term applied to a particular description of joint; thus, to the joint connecting two stones, or other bodies, in such a manner that they cannot slip away from each other without tearing the joggle or joint asunder. A separate piece of hard stone, called a *joggle*, is sometimes introduced at joints of stones exposed to great strains, thus—*See Cuts.*



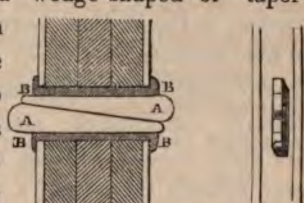
JOINT, the connection or juncture of separate bodies, but applying more particularly to vertical joinings, as in stone-work; those situated horizontally being termed *beds*.

JOINT CHAIR, the chair which secures the jointure of two railway bars together. They are generally made larger than other chairs.—*See Chair*.

JOISTS, the timbers employed in supporting the flooring of warehouses, and other buildings.

JOURNAL, the name given to that portion of a shaft which revolves on a support situated between the power applied and the resistance.

KEY, COTTAR, or COTTREL, a wedge-shaped or tapering piece of iron or wood, which is driven firmly into a mortice prepared to receive the same, to tighten and secure the several parts of any framing or contrivance together, as a rail to a chair, &c., thereby forming a fastening. When a key is passed through a timber beam, or two or more pieces of metal placed side by side, it is customary to clasp them together by irons, termed *gibs*, previous to inserting the keys.



A, A, the Keys. B, B, B, B, the Gibs.

KEY STONE.—*See Arch.*

KING, or CROWN POST.—*See Roof.*

KYAN'S PATENT PREPARATION, a process of preserving timber from the dry rot, recently invented by Mr. Kyan, consisting of a solution of corrosive sublimate, in which the timber is immersed, whereby the primary element of fermentation is neutralized, and the fibre of the wood rendered indestructible. It also effectually seasons the timber, occupying a space of only two or three months instead of from two to six years, which is usually consumed in laying it to dry, by the common method; and it also protects it from the ravages of insects.

The preparation has become generally employed for railway sleepers, and for all timbering employed in engineering works, which, from their exposure to the weather, are very liable to premature decay.

LAND SLIP.—*See Slip.*

LEAF-BRIDGE, or HOIST-BRIDGE, a certain description of bridge, consisting of two opening leaves, and much used formerly, although very seldom employed at the present time.—*See Drawbridge.*

LEAT, an artificial channel for conducting water for the working of water wheels, and for other purposes.

LEGGERS, the name given to the men employed in conveying a barge through a canal tunnel, by means of pushing with their legs against the side walls.

LEVEL, the name given to a tract of low marshy land, or morass, as the Bedford Level, which is the receiver of the waters of nine counties, and which extends into six counties; viz., Northamptonshire, Huntingdonshire, Cambridgeshire, Lincolnshire, Norfolk, and Suffolk; and comprises about 400,000 acres of low land, encompassed in all directions: it therefore becomes very difficult to provide a sufficient outlet to the sea to carry the water off. The works connected with levels are of great importance, and frequently possess extensive embankments and sluices.—A canal, or any particular portion of one, is also termed a *level.—See Drainage for Agricultural Purposes.*

Level, or Gallery (in mining). This term is much used in reference to coal mines, and the levels are usually distinguished from each other by their depth, and are designated 40 fathom, or 50 fathom levels, accordingly.

Level (spirit). The spirit level is an instrument for measuring the rise and fall of the surface of the ground, and used in taking the section of a hill, or proposed line of road, canal, or railway, consisting of a spirit level fixed to a telescope, with screws to adjust it horizontally. The eye of the observer is directed to the object-glass of the telescope, when he observes the height at which the horizontal wire crosses the staff. It is necessary to employ great care in adjusting the instrument, as every thing depends upon the accuracy with which it is performed. Supposing the primary adjustment of the telescope and level together to be correct, the rendering the whole horizontal is easily accomplished by bringing the bubble to the centre of the glass tube. The eye-piece of the telescope must be drawn out until the cross wires appear perfectly distinct, and the screw, acting upon the diaphram containing the wires, must be turned until the smallest gradations are perfectly visible; when any wavering motion appears in either the wires or the staff, parallax is said to exist, which must be removed before any observations are taken.

The "Y level" is the oldest instrument used for this purpose; but "Troughton's Improved" forms a great improvement upon same. "Gravatt's Level," so named from the inventor Mr. Wm. Gravatt, C. E., is at present the favourite instrument among engineers, as it possesses very important advantages over others.

The term *level* is also applied to a perfectly horizontal plane, or line, *i. e.* a line drawn between any two points which are *equidistant* from the centre of the earth.—*See Levelling and Levelling Staff.*

Level, or Paved Crossing (on a railway). Level crossings occur where a railway crosses roads upon the same level; in which case the rails are protected by iron frames and paving.

Level crossings, although of frequent occurrence formerly, are very seldom made at the present time, on account of their prohi-

bition upon highways and turnpike roads, and the accidents sometimes occasioned by them; also the expense of gate-keepers, to attend them.

Levelling, the operation of finding a line parallel with th horizon, from which the rise and fall of the ground may be duly measured, the which is attained by the aid of instruments, on the principle of it being perpendicular to the direction of gravity; but although the horizon is apparently a right line, and level, yet, in point of fact, it is not so, but is a segment of the earth. The globe is an oblate spheroid, flattened at the poles; the polar diameter being 7,808, and the equatorial, 7,924 miles; and a distance of 1 mile upon its surface, gives a depression of 8 inches below the visible horizon due to curvature; at 2 miles, it is 4 times that quantity, or 32 inches; and at 3 miles, 9 times, or 73 inches, and so on, increasing in proportion to the square of the distance; but this fall is slightly reduced by the effects of the refraction of the atmosphere, which incurvates the rays of light proceeding from objects near the horizon in the direction of distant parts, raising them upwards; in other words, the points of observation appear higher than they really are; this rise may be taken at $\frac{1}{7}$th of the curvature, and therefore deducted from it. In ordinary levelling operations, the influence of both curvature and refraction are counteracted by taking observations at equal distances from each side the instrument, when they are each similarly affected, and thereby nullified, their influence in extensive trigonometrical surveys only being calculated and allowed for.

Levelling is usually performed by means of an instrument termed a *level*, and with levelling staffs, the operation being commenced by the staff-man setting up the staff at the starting point of the proposed line of section; the observer then fixes his level at a suitable distance beyond it, either upon the line, or on one side of it, whichever is most convenient; he then adjusts his instrument, and takes a sight at the staff, noting the same in his field-book, the staff-man now proceeds forward, and upon arriving at a suitable point in the line, the observer turns his level, and takes

another observation, noting it as before; and the former sight is denominated the *back sight*, and the latter the *fore sight*; and they are placed in the book, thus—

B. S.	F. S.
7.32	5.20

Sometimes several successive fore sights are taken without altering the position of the level, in which case the fore sights become alternately back sights to the succeeding observations, as—

B. S.	F. S.
7.32	5.20
5.20	2.30
2.30	9.22

It may be remarked that the position and height of the level is immaterial, and any trifling error in the adjustment is also rectified by placing it about midway between the stations. If the section be required for an especial purpose, it is necessary to number the stations, and chain the distances; which are entered in chains and links: miles are marked in the book thus—

CH. LKS.
40.00
60.00
70.00
85.00 = 1 Mile
12.00

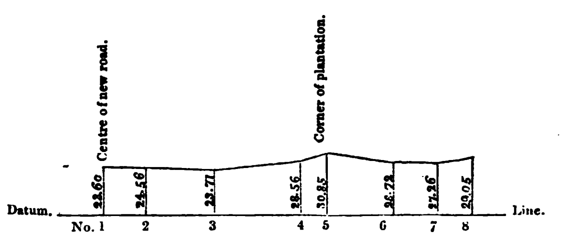
the surplus 5 chains being carried on to the next length of 7 chains, making it 12 chains.

It is essential to hold the chain as nearly horizontal as possible, and not along the surface of the ground. Of course, in running check levels for the purpose of merely ascertaining the general correctness of a section, it is unnecessary to go over the ground in the same line, or to measure it; the comparative level of the several bench marks only being regarded; they may run down a turnpike road, if considered the most convenient.

The following is a good specimen of a field-book, and will explain the method of proceeding :—

Number of Station.	Distance.	Total Distance.	Back Station.	Fore Station.	Rise.	Depression.	Total Rise.	Total Depression.	Observations.
	ch. lks.	ch. lks.	ch. lks.	ft.	ft.	ft.	ft.		
1							23.60		Above Trinity Datum. No. 1, (B. M.) centre of
1 to 2	3.50	3.50	6.26	5.30	.96		24.56		new road to.... (width
2—3	4.60	8.10	7.50	8.35		.85	23.71		40 ft.)
3—4	7.55	15.65	9.10	4.25	4.85		28.56		
4—5	2.30	17.95	7.69	5.40	2.29		30.85		No. 5, corner of planta-
5—6	9.16	27.11	2.17	4.30		2.13	28.72		tion.
6—7	7.45	34.56	7.50	8.96		1.46	27.26		
7—8	4.18	38.74	9.28	7.49	1.79		29.05		

The following cut represents the section of the above, the horizontal scale being 4 inches to the mile, and the vertical 100 feet to the inch :—



The 1st column gives the number of the station; the 2nd, the length or distance between the sights; the 3rd, the total distance from the first station; the 4th, the height of the back sight; the 5th, the height of the fore sight; the 6th and 7th gives the difference between the height of the sights, the rises being placed in the 6th, and the falls in the 7th column; the 8th and 9th gives the reduced or total level above or below the first station or datum line, the total rises being reduced in the 8th, and the falls in the 9th column; the 10th, or last column, is left for notes of the crossing of roads, rivers, &c., and to enter the bearing of the line of levels; also any necessary observations upon the local nature of the country, soils, &c., may be advantageously

placed therein. It is occupied in the diagram by memoranda of the situations of the stations.

The line parallel with the horizon, mentioned at the commencement of this article, is called the *datum line*, and is generally on a level with the high water spring tides (Trinity datum), or low water spring tides, or some other fixed mark, or at the level of the first station, or 50 feet, or 100 feet, below it.—*See Datum Line.*

It may be remarked, that in common with all surveying operations, the correctness of the instrument should be proved by experiment, and the chain should also be measured previous to commencing; a strong stand is also desirable for the level, with legs formed out of whole pieces, instead of being joined in the centre, as frequently made. When the instrument is adjusted, and the observations are proceeding, the movements around it should be very few, and carefully made, particularly when situated on boggy ground, as they are very likely to throw the whole out of adjustment; and, for the same reason, the telescope should be capable of turning upon the application of a very small degree of force.

In plotting out the work and drawing the section, it is customary to adopt a larger vertical scale, compared with the horizontal, in order to show the inequalities of the ground plainer.—*See Section.*

A section is always commenced and finished at a bench mark, consisting of some fixed object, (*See Bench Marks*). If none should exist on the line of survey, it is necessary to make some, for the purpose of reference at any future time, and for continuing, checking, or deviating from the line of levels, if found necessary; therefore, upon the spirit level being fixed, the difference between the bench mark and the first station forms the commencement, the level of the bench mark being entered first, in the column of total rises, or total falls, as the case may be (although the first station should be situated at a bench mark if possible): if, at the close of a day's levelling a good bench mark cannot be found, a stake may be driven into the ground as a temporary bench mark, of which no notice need be taken in the field-book.

In the event of meeting with obstructions in the line, as woods, lakes, forbidden property, &c., the levels must be taken round them: if the distance should extend far, and the opposite side cannot be seen, the plan must first be taken, then plotted, and the proper direction of the line marked upon it, also measured and set off on the ground, by which the levels may be readily carried round; and upon arriving at the ultimate point, the original bearing of the line must be taken, which will give the true direction of the line of section. Lakes, ponds, woods, and buildings, may be readily passed, by setting off a right angle, and continuing the line until it clears the obstruction; next set off another right angle, and again another, which carries it into the line of section; the length of the second line must, of course, be equal to that of the first line set off.—*See Level (Spirit).*

LEVELLING STAFF, a graduated rod or staff, which is advanced alternately with the spirit level, denoting by the graduations bisected by the latter the rise or fall between any two points.

The improved levelling staff with inverted figures, which accommodates itself to the inverting telescope, whereby the figures may be read off by the observer in their proper position, tends much to prevent errors, and facilitates the operation. Two staffs are sometimes used which are moved on alternately, one being applied for the back, and the other for the fore observation.

LIFT-WALL, the cross wall of a lock chamber.

LIGHT-HOUSE, a certain erection, generally in the form of a tower, built upon or adjacent to dangerous rocks, for the purpose of warning ships of their situation; or along the sea coast, as landmarks, lights of various descriptions being introduced upon the top at night: a gallery, or balcony, usually runs round the lantern on the outside. Light-houses, of a similar description, are also frequently erected at the extremity of one of the arms forming the entrance to harbours, for the purpose of guiding the vessels in and out during the night, &c., which are generally called "*harbour lights.*"

The present Eddystone Light-house, which is situated at the

entrance to Plymouth Sound, and was commenced in 1756, by Mr. Smeaton, is one of the most celebrated, presenting a fine specimen of scientific construction, being situated upon an extensive reef of rocks, known by the name of the "Eddystone," the scene of many shipwrecks, about 9½ miles from the Ram-head, or nearest point of land.

Elevation of the Eddystone Light-house.

It is built upon an inclined piece of rock, upon which the foundation stones are stepped down. The height to the top of the cupola is about 86 feet at the highest level of the rock or head-

land point, and about 94 feet at the lowest level; the building is carried up solid as high as there was any reason to suppose it was exposed to the heavy stroke of the sea, viz. to 35 feet 4 inches above its level, and 27 feet above the top of the rock, or common spring tide high water-mark; the entrance is about half-way up the latter, and the ascent is made by a well staircase in the centre; the sides of the stones forming the courses of this portion are worked into one another, thus: oak vertical wedges were introduced into grooves prepared to receive them in the masonry, whereby the stones were secured from the effects of the sea, during the intervals the works were obliged to be left; each course was likewise secured to the one below it by oak trenails, which were driven through the upper course, entering 9 or 10 inches into the one beneath it, and these trenails were again split and wedged to secure their safe purchase, as the violence of the waves was such, that the mortar from the beds and joints of the stones forming the upper courses were washed away when the works were left during the intervals of stormy weather; these courses were further secured together by marble joggles or plugs, which were introduced between the beds of the stones, and well wedged and flushed with mortar. The next portion, extending to the cap of the pillar, forming the surface of the balcony, or gallery, round the base of the lantern, is carried up in stone walling, varying in thickness from 2 feet 4 inches at the bottom to 1 foot 6 inches at the top, which is arched over in masonry, and there are three intermediate floors between them, a well-hole being left in the centre of each for communication, which is effected by means of ladders; and 2 tier of strong chain-bond is laid in each floor in the middle of the walls, the several joints of the stones of this portion of the building have grooves worked into them, into which thin pieces of marble are joggled; they are also well cramped together, and a wall, about 6 feet 6 inches high, and 1 foot 2 inches thick, is carried up above the capping, upon which the lantern rests.

Plan of the 14th Course.

The Bell-rock Light-house, erected also on a dangerous reef in the Frith of Forth, by Mr. Stevenson, and finished in the year 1811, is another excellent specimen. It is 42 feet in diameter at the base, and 13 feet at the top, the total height being upwards of 100 feet.

Section of the Eddystone Light-house.

LIME, a valuable substance much used in building, and for other purposes, being the most essential ingredient in all cements; it forms one of the primitive earths, although never found native, or in a state of purity, but is always combined with acids,

particularly carbonic, in which it exists in prodigious quantities: marble, limestone, and chalk, are all carbonates of lime, and gypsum is sulphate of lime. Lime may be prepared from any carbonate of lime, as limestone, or chalk, calcined or well burnt in kilns for some time to a white heat, by which the carbonic acid and acid contained in those substances are expelled, and the earth is left in a fragile mass, having very little coherence, and is therefore easily reduced to powder, when it is called *quick lime*, in which state it shows a great disposition for water; upon applying which it instantly swells and cracks, producing a considerable degree of heat (it will absorb one quarter of its weight of that fluid, and yet appear dry), it then falls into a fine white powder, when it is called *slack lime*.

Stone lime is generally used for engineering works, and the harder the stone the better is the lime produced from it. Brown stone lime is said to be the best for all kinds of cements, although blue lias lime is considered by some to be superior, as it stands the action of water exceedingly well; it was used by Mr. Smeaton in building the Eddystone Lighthouse, where it has succeeded after all other limes had failed. Good chalk lime, although said to be inferior to stone, is yet much esteemed. Lime should always be kept under an enclosed shed, particularly chalk lime, as it suffers considerably from exposure to the air: the efficacy of lime also depends materially upon being well burnt, after which process it should be used as soon as possible.—*See Hydraulic Lime.*

LIME STONE, or CALCAREOUS STONE, the stone from which lime is produced.—*See Stone and Lime.*

LINING (in canal and other hydraulic works), a term applied to puddle laid along the bottom and upon the sloping sides of canals, whereby it prevents the water from escaping; it is usually laid about 2 feet in thickness. A small portion of water will always percolate through the banks of canals immediately after their formation, but it gradually subsides as the soil consolidates.—*See Canal.*

LINK, a certain portion of a chain. Gunter's chain, which is

that usually employed in surveying, contains 100 links, each measuring, with the connecting rings, 72 $\frac{92}{100}$ inches.

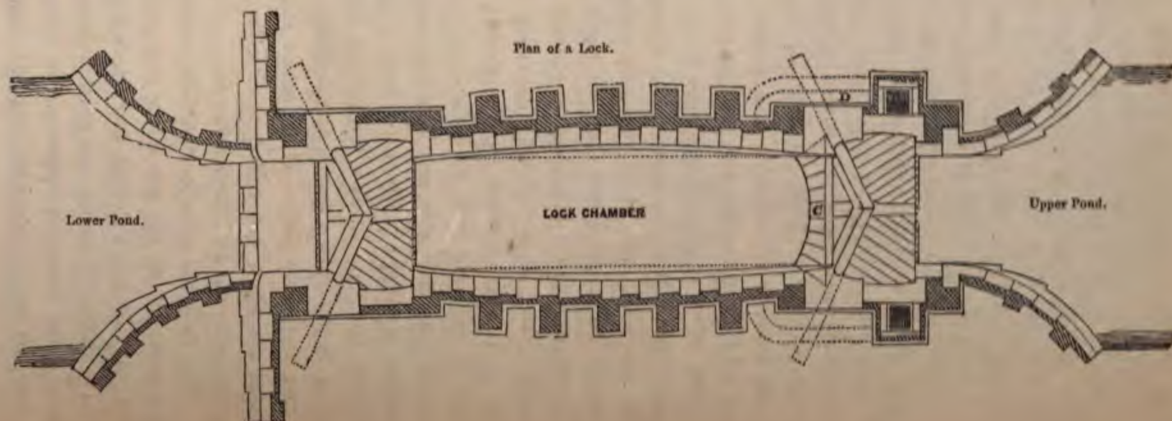
Lock, or Hydraulic Lock, a small lock of modern invention, and of frequent occurrence in the line of a canal; also at the entrance of docks, basins, &c., constituting a contrivance for passing boats from one level to another.

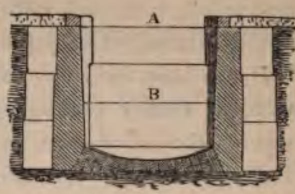
Locks are provided with gates at each end, and are made sufficiently large to receive the largest boats navigating the canal upon which they are constructed. The upper portion of the canal is generally called the *upper pond*, and the other the *lower pond*, the difference between the levels being termed the *lift of the lock* (which varies from about 3 to 12 feet—the greater the lift the more water is consumed); that portion of the lock enclosed by the gates is called the *lock chamber*, the size of which is regulated by the boats employed upon the canal. A (*in the sections*) represents the level of the upper pond, and B that of the lower; C is the lift wall, and D, D the side culverts. The lock chamber should be rather wider than the boats used upon the canal, and the utmost care is necessary to prevent the water from the upper level making its way below, and rising up through the bottom of the lock, and undermining the works; the bottom is constructed with an inverted arch, to counteract any defect of this kind, the which also excludes any humidity in the soil, and diffuses the weight of water equally throughout. The recess into which each leaf of the gate turns is termed the *gate chamber;* the gate post, hung in the hollow quoin, is called the *quoin* or *heel post*, and the other the *mitre post.* The bottom framings, against which the gates are shut, are called *mitre sills,* and are distinguished as *upper mitre sill* and *lower mitre sill.*

The portions of a lock at each extremity of the lock chamber are termed *bays,* and are either *fore* or *tail bays* accordingly, they are usually finished with circular wing walls, extending to the full width of the canal, and carried down below the bottom of the same; and bumping apparatus is sometimes formed against the latter, by which they are protected from any shock of the boats

Longitudinal Section of a Lock.

Plan of a Lock.





Transverse Section.

or boat-hooks; grooves are generally made in the head and tail bay walls, for the insertion of stop planks, to shut off the water when repairs are necessary.

When a boat is required to be passed from the higher to the lower level, it is first floated into the lock chamber, and the upper gates closed; the water is then allowed to escape from the lock chamber to the lower level, which is effected either by paddles formed in the gates, or by side culverts; the boat being thus sunk to the lower level, the lower gates are opened, and it is taken through: and the boats are passed up by a similar process, only reversed. Some locks are constructed sufficiently large to allow of two boats being passed up or down at the same time; and others effect the same by two distinct chambers.

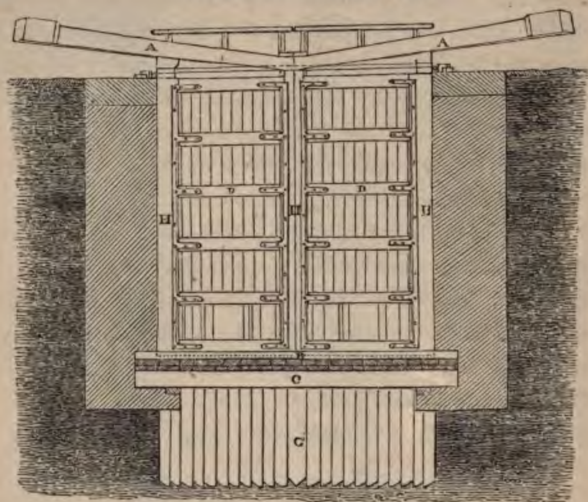
Lock-Gates, or Hatches, the framed gates employed on rivers and canals, for penning back the water, which consist of two leaves, and are opened either by means of balance-beams, situated on the top of the gates, or by boat-hooks: a large gate running upon wheels is opened by means of a windlass and chain.

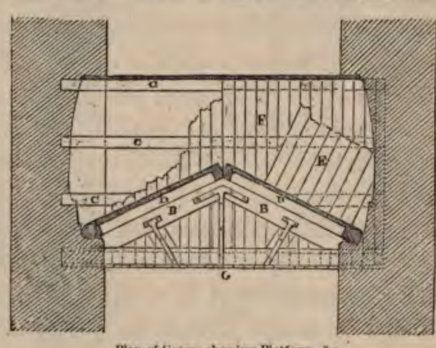
The gates of a lock are termed either *upper* or *lower gates*, according to their situation; they are generally formed of strong oak framing, the upright frame, or posts, at each side being called *quoin* or *heel posts*, and the others *mitre posts*, according to their situation, and horizontal pieces are framed into them, termed *rails*; their tops are finished by long heavy beams, termed *balance-beams*, which are for the purpose of opening and shutting the gates, these rest upon the quoin posts, and are morticed into the mitre posts; strong planking is nailed or trenailed on to the leaf framing, which is sometimes laid in a diagonal direction, and a slight foot bridge is usually formed on the top of the gates. The quoin posts rest upon an iron pin, which turns in a socket secured to the platform, and the upper part is enclosed by an

iron collar, connected with irons fastened to the stone curb, and usually denominated *anchor irons.*

It has been found by experience, that lock gates, in common with all timber framing, stand better when secured together without the aid of irons, by means of dove-tailed tenons, wedges, and pins, as iron soon affects those parts in immediate contact with it.—*See Anchor Irons, and Paddle or Clough, &c.*

Elevation of Inner Side of a Lock Gate.





Plan of Gates, showing Platform, &c.

A, A, the balance-beams, by which the gates are opened and shut.

B, B, the clap-cill and frame.

C, C, the cross bearers, resting upon plates, and upon which the planking is laid.

D, D, the rails or framing of gates, to which the leaf planking is secured.

E, the upper diagonal planking.

F, the bottom planking.

G, the elm sheet-piling, for protecting the platform.

H, H, the quoin, or heel posts.

I, I, the mitre, or meeting posts.

LOCK SILL, or CILL, the bottom framing against which the gates are shut.—*See Lock.*

LOCK-WEIR, a weir furnished with a lock, for the transport of boats from one level to the other.

LOCOMOTIVE ENGINE, a motive steam-engine constructed on the high-pressure principle, and adapted to run on roads and railroads, being employed in conveying passengers and merchandise along the line.

Locomotive engines differ considerably from other steam-engines in their mode of construction, as numerous modifications from the latter became necessary to render the machine suitable for a rapid transit; the foremost of which is the combining of the engine and boiler together, the boiler is also formed of much less dimensions in proportion to its power, and the size of the cylinders are reduced; the several parts of the framing is also secured together in a stronger manner than usual, whereby the whole is rendered proof against the sudden shocks and strains to which it is subjected; the motion of the piston-rod is transferred to the wheels, either by connecting rods fixed upon one of the spokes of the wheels, or it is effected by cranks fixed upon the axles, which thereby cause the wheels to revolve: the latter system is the most convenient and direct, and is in almost general use; although the crank, being subjected to very great strains, is rather liable to fracture, the former may consequently be considered to be the strongest method.

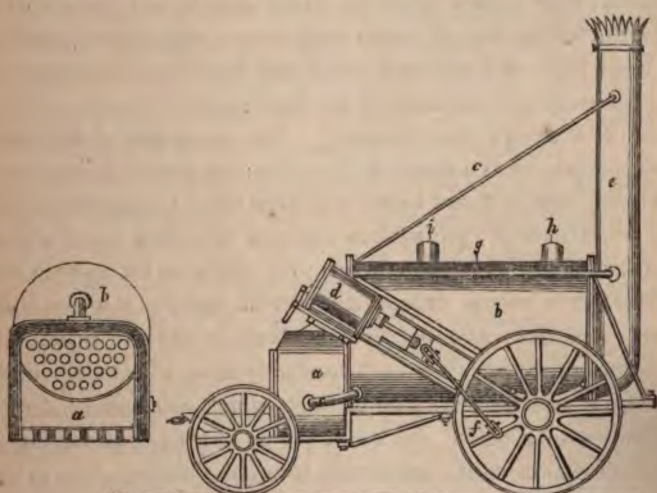
The honour attached to the inventor of the locomotive engine is undoubtedly due to Mr. Trevithick (although Mr. G. Stephenson has the credit of perfecting it); the first one having been constructed by Trevithick and Vivian in about the year 1802, which was tried upon the common roads. It was supposed at the time, but erroneously, as experience has since shown, that the wheels did not possess sufficient power of adhesion to the road to impel the engine forward; and various contrivances were consequently attempted in other engines to increase the same by the aid of propellers or levers, whereby it was pushed along, and which acted upon the ground somewhat similar to the feet of horses: among the foremost of these was Mr. Gurney's common road locomotive, as originally constructed; the propellers being afterwards found useless, were removed, although they have been described as forming the chief peculiarity of his patent. Mr. Gurney's carriages obtained a very great share of public patronage and consideration: indeed they have been the most successful of any.

Trevithick and Vivian also constructed another modification of their patent steam-engine, and applied it upon a very indifferent tramway, where it realised all that could be reasonably expected; it was worked by only one cylinder, which was placed vertically; and it got over the centres or dead points by the momentum of the carriage when in motion.

The first public railway, worked by locomotives, was the Stockton and Darlington, by Mr. G. Stephenson, which was opened in 1825; the locomotives were worked by vertical cylinders, the motion being communicated to the wheels similar to the last-mentioned engine, and all four wheels acted upon it by means of an endless chain running round cog-wheels fixed on the axles. Although far from perfect, these continued to be the most effective engines at work, until the opening of the Liverpool and Manchester Railway; and all engines, up to this period, may be described, generally, as being of very poor construction, having one flue passing through the boiler, and returned again to the fire-box (the Trevithick plan of boiler), at which end the

chimney was situated; and a greater velocity than 8 miles an hour could never be attained by them, owing to their small extent of evaporating surface: they did not possess $\frac{1}{14}$th the power of the present locomotives.

The directors of the latter railway having, in the year 1829, offered a premium of £500 for the best locomotive engine, gave the first stimulus to the subject, the stipulations and conditions being as follows:—viz., "To consume its own smoke; to be capable of drawing three times its own weight at 10 miles an hour, with a pressure on the boiler not exceeding 50lb. upon the square inch; the whole to be proved to bear three times its working pressure—a pressure gauge to be provided; to have two safety-valves, one locked up: the engine and boiler to be supported on springs, and rested on six wheels, if the weight should exceed $4\frac{1}{2}$ tons; height, to the top of the chimney, not to exceed 15 feet; weight, including water in boiler, not to exceed 6 tons, or less, if possible: the cost of engine not to exceed £550." The "Rocket" engine, by Messrs. Booth and Stephenson, proved the successful one, in the boiler of which tubes were introduced for the first



Elevation and Section of the "Rocket" Locomotive Engine.

time, which greatly increased the evaporating powers of the engine, and formed a considerable improvement.

a, the fire-box, which is surrounded with water on every side, except that perforated for the reception of the fire tubes.

b, the boiler in which the steam is generated, containing 25 fire tubes.

c, one of the side pipes for conducting the water from the boiler to the casing round the fire-box.

d, one of the steam cylinders.

e, the chimney by which the smoke and condensed steam escapes.

f, one of the connecting rods for communicating the motion of the piston-rod to the driving wheels.

g, one of the eduction pipes, through which the steam escapes into the chimney, after performing its office in the cylinders.

h and *i*, the safety-valves.

The boiler of the "Rocket" locomotive was 3 feet 4 inches diameter, and 6 feet long, having flat ends; the lower half was kept constantly filled with water, and 25 copper tubes, of 3 inches diameter, were passed along its whole length, and fixed water-tight, the further ends of which were open to the chimney, and, at the other ends, to the furnace (the tubes employed in locomotives at the present time are of much smaller diameter, but three or four times the number of the "Rocket"). The upper half of the boiler was appropriated as a reservoir for steam: the square furnace-box, was 3 feet long by 2 feet broad, and 3 feet deep, the fire bars laying at the bottom of it; the surface exposed to heated air, or flame, from the furnace 117.8 square feet; the whole of the furnace was enclosed in a casing, except the bottom and the side next the boiler; and the space between the furnace and the casing was 3 inches in the clear, and kept constantly filled with water: there was also a pipe from the side of same, which communicated with the underside of boiler, and another pipe was fixed at the top of it, which conducted the steam from it into the boiler. The cylinders had a stroke of 16½ inches, and were placed in a diagonal

direction upon each side at the extremity of the boiler, each working a wheel of 4 feet 8½ inches diameter. The principle of generating steam was by the exhausting power of the chimney, assisted by the impulse of the steam from the cylinders, which escaped from them into the chimney by two pipes, one on each side, called the ejection pipes.

	Tons.	cwt.	qrs.	lbs.
The engine weighed	4	5	0	0
Tender, with water and coke . .	3	4	0	2
Two loaded carriages attached . .	9	10	3	26
Total weight in motion . .	17	0	0	0

The evaporating surface of the boiler was three times the extent of the former engines, which weighed upwards of 7½ tons, to which its success is mainly attributable; it evaporated 114 gallons of water an hour, and consumed 217lb. of coke in that time, and it attained a speed of 29 miles an hour, and an average velocity of 14½ miles an hour.

Although locomotives have since been considerably modified, yet the above engine has formed the basis of all the many great improvements which have taken place in them. The cylinders have been removed from the outside of the boiler to the inside, and the piston rods placed underneath, instead of on the outside of the wheels; they are also connected with the latter by means of cranks placed upon the axles of the driving-wheels at right angles with the same; a warm air chamber has also been made at the upper end, and a blast-pipe introduced in the chimney, whereby the draught of the furnace is considerably increased.

It was soon after found, that by constructing engines of greater size, the increased evaporating powers would make ample amends for the additional weight, and a strong desire was accordingly manifested of having heavier engines on the Liverpool and Manchester Railway, but owing to the rails not being sufficiently strong to carry them, they were found objectionable; and there

was accordingly a constant struggle between light and heavy engines for some time, but the line being now relaid with heavier rails, they are exclusively used. The locomotives in general use at the present time, upon public lines of railway, weigh from 9 to 13 tons, and are mounted on six wheels, which are frequently coupled to increase their power of adhesion. The framing of the engine is usually placed on the outside of the wheels, but Mr. Bury places the framing of his engines on the inside, by which he reduces the length of the axle, and consequently increases its strength. The slide-valves are shifted by the engineer by means of the connecting rod, or hand-gear, at starting and stopping an engine only; when at work, the engine performs it. A larger proportionate passage is required for the entrance of the steam in locomotives than in stationary condensing engines; the usual velocity of the piston being about 440 feet per minute, or double that of the latter, when running at a rate of 25 or 26 miles an hour: they move at 700 feet per minute, when moving at 40 miles an hour; a proportion of $\frac{1}{14}$th the area of the cylinders is considered the best for the area of the steam port.

The power of a locomotive engine varies according to the velocity with which it is propelled, and it cannot be estimated in the same manner, as other engines, viz., taking the actual force upon the piston and the velocity of its motion, as it is very difficult to ascertain the effective pressure of the steam upon the piston, in consequence of its often differing very considerably from that in the boiler, and on account of the large amount of resistance of the waste steam, owing to the great velocity with which the piston moves. The only true method of determining the power of a locomotive is, therefore, by experiment.

The extent of power of a modern locomotive engine, having 12 inch cylinders, and an 18 inch stroke of piston, has been stated at about 38 or 40 horse power at high velocities upon a level plane, and 70 to 80 horse power at a slow rate of speed; and their general performance has also been estimated by other engineers at from 30 to 40 tons, moved at the rate of 15 miles an hour; accord-

ing to which the following Table shows the load it will have at different inclinations at plane :—

Inclination of Planes.	Gross load in Tons, which a Locomotive Engine, capable of taking 30 tons at 15 miles per hour, will drag at the under-mentioned Velocities, in miles in an hour.					Gross load in Tons, which a Locomotive Engine, capable of taking 40 tons at 15 miles per hour, will drag at the under-mentioned Velocities, in miles in an hour.				
	Miles. 10.	Miles. 12.	Miles. 14.	Miles. 16.	Miles. 18.	Miles. 12.	Miles. 14.	Miles. 16.	Miles. 18.	Miles. 20.
Level . .	53.4	45.	34.28	26.25	20.	60.	45.70	35.	26.66	20.
1 in 4480	50.85	42.57	32.62	24.97	18.97	57.1	43.5	33.3	25.3	19.
1 in 2240	48.51	40.87	31.12	23.85	18.15	54.5	41.5	31.8	24.2	18.1
1 in 1120	46.5	39.07	29.77	22.8	17.32	52.1	39.7	30.4	23.1	17.3
1 in 1000	43.56	36.75	27.97	21.45	16.27	49.	37.3	28.6	21.7	16.3
1 in 900	42.9	36.3	27.6	21.15	16.12	48.4	36.8	28.2	21.5	16.1
1 in 800	41.7	35.15	26.77	20.47	15.6	46.9	35.7	27.3	20.8	15.6
1 in 700	41.25	34.05	25.95	19.87	15.07	45.4	34.6	26.5	20.1	15.1
1 in 600	39.	32.85	24.97	19.05	14.55	43.8	33.3	25.4	19.4	14.6
1 in 500	37.05	31.2	23.77	18.22	13 87	41.6	31.7	24.3	18.5	13.9
1 in 448	35.61	30.0	22.87	17.47	13.27	40.	30.5	23.3	17.7	13.3
1 in 400	33.75	28.8	21.97	16.8	12.75	38.4	29.3	22.4	17.	12.8
1 in 350	32.7	27.37	20.85	15.97	12.15	36.5	27.8	21.3	16.2	12.1
1 in 300	31.44	25.8	19.65	15.07	11.47	34.4	26.2	20.1	15.3	11.4
1 in 250	28.2	23.77	18.57	13.87	10.57	31.7	24.1	18.5	14.1	10.6
1 in 200	25.11	21.22	16.12	12.37	9.37	28.3	21.5	16.5	12.5	9.46
1 in 150	21.36	18.	13.65	10.5	7.95	24.	18.2	14.	10.6	8.
1 in 100	17.55	14.77	11.25	8.62	6.58	19.7	15.	11.5	8.78	6.58

It is generally considered injudicious to work an engine regularly to the utmost of its power; the load should, therefore, be always a little less than it is capable of drawing, to allow for the variation of level in the line, and other contingencies; and extra power may yet be obtained, if required, for the inclined planes, by partially stopping the flow of water into the boiler at the time of passing up, which increases the power of the steam, although not to much extent. The water lost by the steam blown away in a locomotive and other steam engines is replaced by an equal quantity of water at each stroke of the piston, being supplied by small force-pumps from the tender, and worked by the engine.

Engines are generally oiled by means of syphon wicks, or by cocks and tubes; and the engine-man should carefully examine the oil cups and syphon wicks previous to starting, also the water-gauge and the other parts of the engine; and, as he sets her

agoing, should try the hand-gear and force pumps; the condensed steam-cock should be kept open as long as possible, and not shut until just before the train starts. During running, the water-gauge should be tested by the gauge-cocks, if considered necessary, and the cocks should always be turned before the supply pumps are used.

The locomotives may be frequently observed running up and down a line of railway for a short distance in the vicinities of the engine-house and depôts; this is for the purpose of pumping the water from the tender into the boiler, the supply pumps, as before stated, being worked by the engine; it is obviated, in some cases, by the locomotive being placed upon the circumference of large wheels situated beneath the line, instead of upon the rails, when the only effect produced is the turning of these friction wheels, the locomotives remaining stationary.

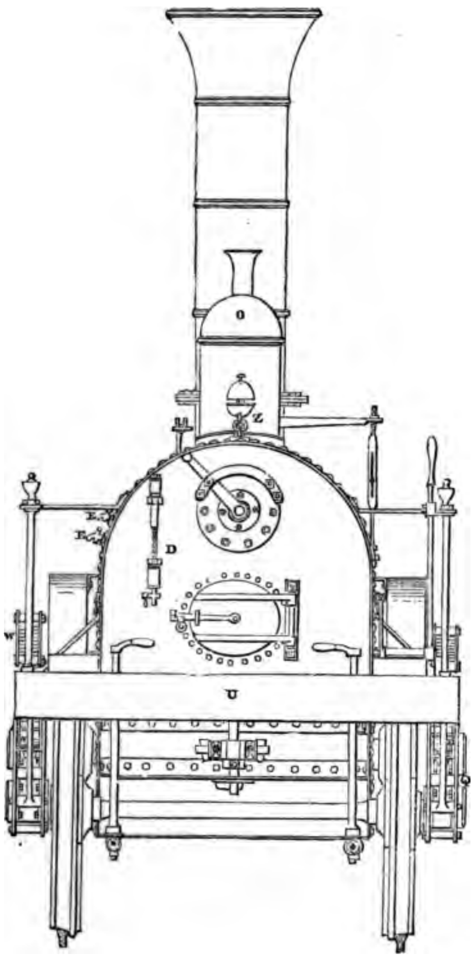
The boiler forms the limit to the power and speed of a locomotive, as each stroke of the piston consumes two cylinders-full of steam, the same causing one revolution of the wheels; a certain quantity of steam, may, therefore, be said to represent a certain number of feet travelled over; and the cylinders are generally capable of more work if a greater quantity of steam could be supplied to them: the diameter of the pump and feed-pipes are also not sufficiently large to feed the boiler at very high velocities, which consequently causes a lack of steam; the boilers of stationary engines, on the contrary, may be enlarged without difficulty, if the engine requires it.

Nearly one-third of the power of locomotive engines is absorbed in *preparing to move a load*, and it is the same for great as for small loads; the wear and tear of the engine also bears the same ratio; and the current expenses, as that of the stations, the sum for direction, wages of engineers, attendants, &c.; it is, therefore, of the utmost importance that the goods and passengers upon a railway should be conveyed in large masses.

The consumption of fuel of locomotives is regulated by the load; with a full load it amounts to about ¼lb of coke per ton

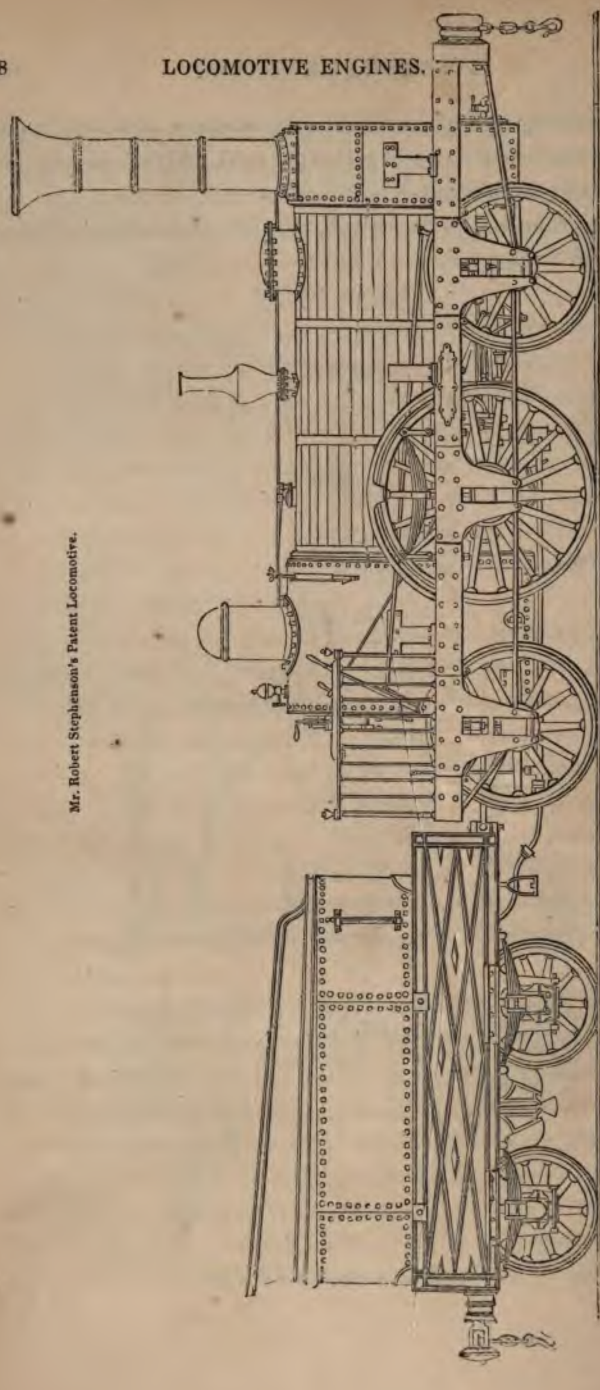
per mile, taking the gross weight (the quantity of water evaporated is rather less than $\frac{1}{4}$ of a gallon per ton), and the consumption of it is nearly double with a light load.

The following cuts represent Mr. Robert Stephenson's Patent Locomotive Engine :—

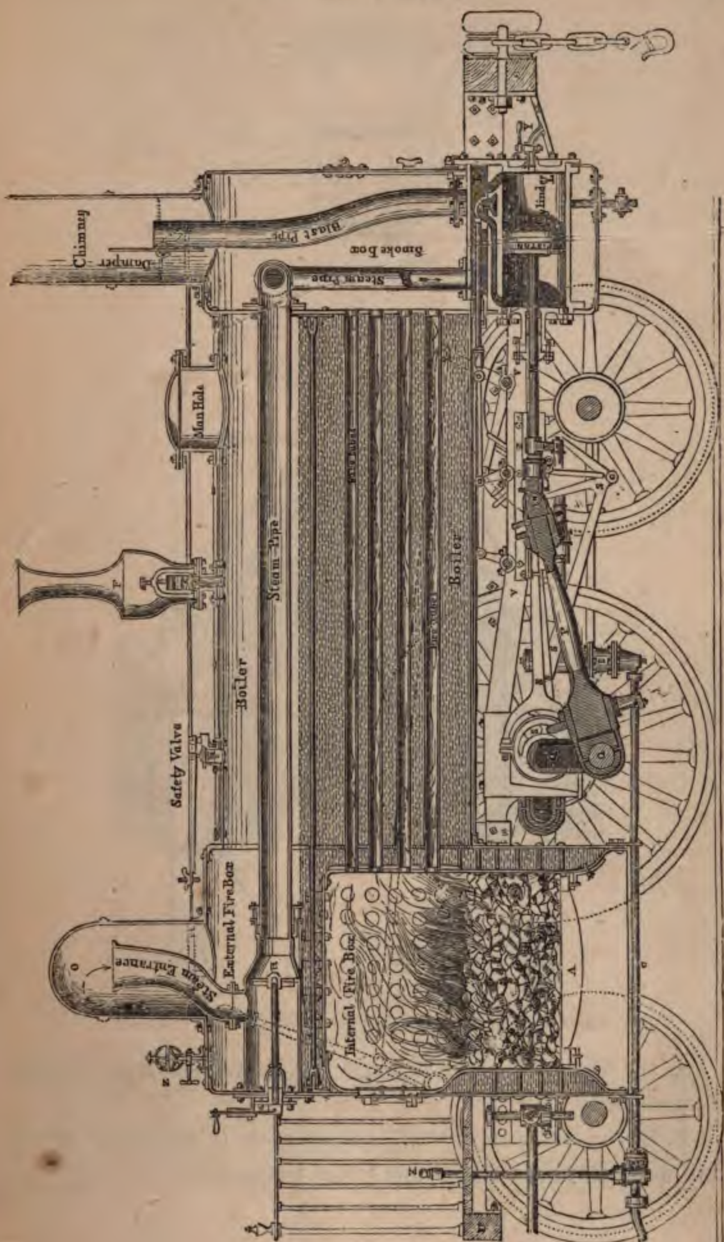


End Elevation. Scale $\frac{3}{8}$ of an inch to the foot.

Mr. Robert Stephenson's Patent Locomotive.

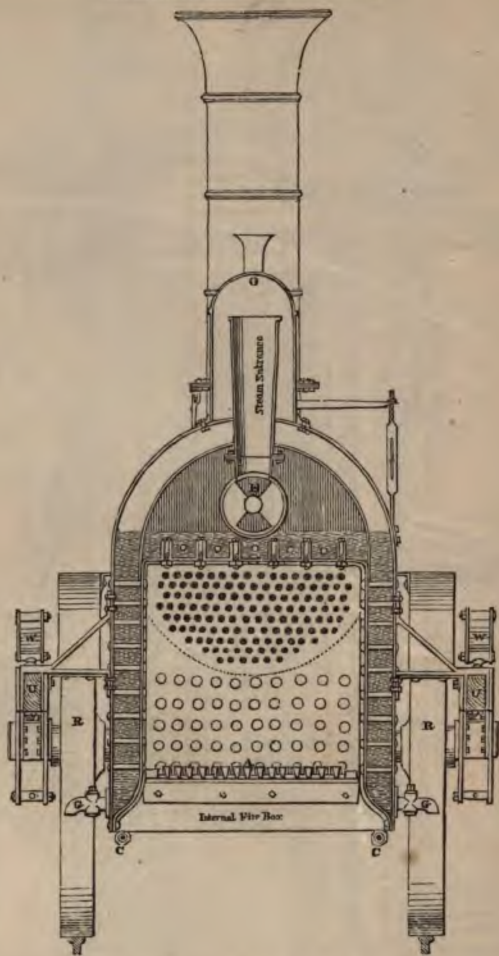


Side Elevation, with the Tender attached. Scale ¼ of an inch to the foot.



Longitudinal Section, showing Construction. Scale ⅛ of an inch to the foot.

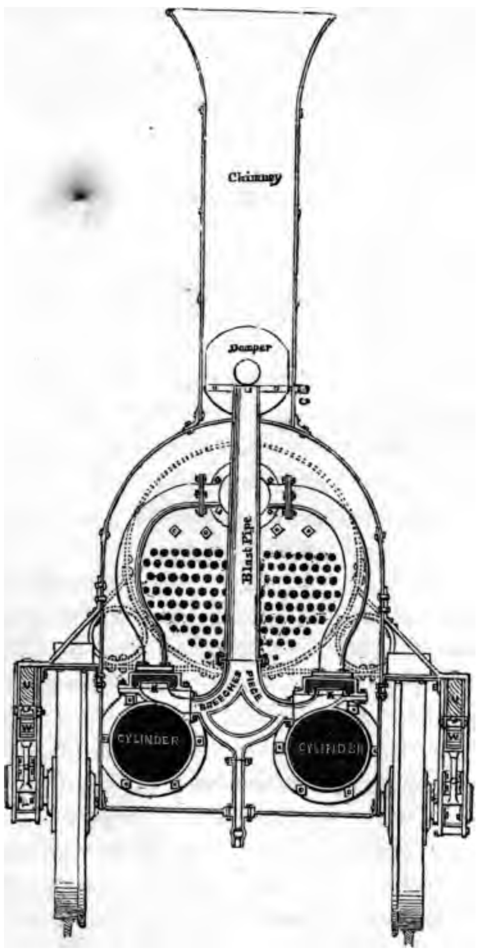
Mr. Robert Stephenson's Patent Locomotive.



Transverse Section taken through Smoke-box. Scale $\frac{3}{8}$ of an inch to the foot.

A, the fire-grate, which is situated at the bottom of the internal furnace-box.

B, B, the feed-pumps which supply water to the boiler, which are worked by an arm attached to the piston-rod.



Transverse Section taken through Smoke-box.

C, C, the suction-pipes to same.

D, the gauge for regulating the height of water in the boiler.

E, E, the gauge-cocks for trying the same.

F, the lock-up safety-valve, over which the engineer has no controul.

G, G, the blow-off cocks, through which the water is blown when the boiler undergoes cleansing.

H, the regulator, which is fitted to the steam-pipe, by which the engineer regulates the supply of steam to the cylinders as may be required.

I, I, the slide-valves forming the communication between the steam pipe and the cylinders.

K, K, the steam-chests in which the same work.

L, one of the cylinder covers, which are fixed air-tight.

M, one of the piston-rods.

O, the steam-dome or cover, being placed over the steam-pipe.

P, one of the connecting-rods, which is attached to the last by means of cross-heads.

Q, Q, the cranked axle.

R, R, the driving-wheels.

S, S, the eccentrics and accompanying gear for reversing the motion of the engine.

[illegible] the principal or outside framing, upon which the springs [illegible] the framing employed within it being termed [illegible]

[illegible] ascertaining the flow of water in [illegible]

[illegible] the priming water from the cylinders; [illegible] connected with the blast-pipe or a like [illegible]

[illegible] steam-whistle, for giving signals as occasion may [illegible]

[illegible] modern locomotives take about 8lb. of fuel to evaporate [illegible] foot of water (which is nearly the same that is required by stationary engines); as much as 18lb. were consumed by the old locomotives to accomplish the same, owing to their evaporating surface being considerably less. The cost of a locomotive engine and tender is about £1,200, and the annual repairs are stated at £800.

There have been several locomotives constructed, with a view

to their running on common roads, as before stated, which are necessarily of much less weight than those employed on railways, and they usually possess a greater degree of power in proportion to their weight. Mr. Gurney was among the foremost in

Mr. Gurney's Patent Road Locomotive, with a Carriage attached to it.

introducing them; he proposed having the carriage containing the passengers attached to the propelling carriage, or engine, and he considered that if his conveyance was employed instead of horses the total weight upon the road would be about the same in either case; thus, supposing the average weight of 1 horse to be 10 cwt. it would give 2 tons as the weight of 4, which is about that of his propelling engine, and the passenger-carriage (containing 18 persons) would be of the same weight as the stage-coach drawn by the horses; but as horses cannot work above 1 or $1\frac{1}{4}$ hours per day, from 25 to 32 horses are constantly required to work 8 hours, or the length of time a locomotive may be readily run per day, which number of horses it may therefore be said to be equal to; although his engine is calculated to be of only 12 nominal steam-engine horse power: notwithstanding, where a speed of 4 miles an hour only is required, horses are the cheapest. If the engine is employed to draw carriages, as represented in the above cut, they should not exceed 3 tons, nor the engine 2, or $2\frac{1}{2}$ tons. An engine, with a carriage, can turn a circle of 10 feet inner diameter, and be stopped within 6 or 7 yards. The ordinary pressure on Mr. Gurney's boiler is 70lb per square inch; it consequently blows with that pressure, and generally lifts the valve: when the carriages stop, it is sometimes increased to 100, and 130 is the greatest

pressure it is liable to be subjected to; 20lb. is also the utmost pressure on the piston: the danger of the boiler of a road locomotive bursting is not so great as that of the horses running away. Mr. Gurney has thrown out an idea of adopting a locomotive, both for high and slow velocities, by a very simple contrivance; viz., by using wheels 5 feet diameter, when the load is light, and a great degree of speed is required, and substituting smaller ones, when the load is heavy, say 2 feet 6 inches diameter, and a slow velocity only is necessary; the power with the latter would be double that of the former, but they would travel at only half their velocity. An advantage is gained by quick travelling, as the momentum assists in overcoming the inequalities of the road, in a similar manner to the action of a fly wheel. One of Mr. Gurney's locomotives, weighing 2 tons, drew 11 tons, inclusive of the engine, the road being hard and good, although it undulated. The width of the tires of the wheels were originally 2 inches, but he has found 3½ inches a more advantageous width, particularly for the roads.

Mr. Hancock's common road locomotive was the first publicly run upon a road for hire, which occurred in the year 1831; in which case the engine was adapted for the reception of passengers, and was capable of containing 16 persons, independent of the engineer and guide; the machinery being situated behind the carriage, and the weight was about 3½ tons, without passengers, and exclusive of the engines, boilers, coke, water, &c. The inventor states, that it requires about 20 minutes to get up the

Mr. Hancock's Patent Road Locomotive.

steam, the same consuming 1 bushel of coke, taking in water according to circumstances—say every 8 miles, and about 7 or 8 cwt. at a time; the carriage can be turned in little more than 10 feet, and stopped in a much shorter space than a coach; the pressure of the steam in the

boiler is much the same as in Mr. Gurney's, but he has worked it at a greater pressure. The fire is blown by a rapid current of air produced by a fanner, which is turned rapidly round by the engine, instead of the draught being effected by a high chimney. One driving wheel is generally found sufficient; but, on slippery roads and steep hills, both hind wheels are connected with the engine; he has accomplished 1 mile up hill, at a rate of 17 miles an hour.

It may be very fairly stated, that the several unsuccessful attempts that have been made to introduce locomotives upon common roads, have not been caused by any imperfection in their mode of construction, neither are there any practical difficulties connected with them that could not be surmounted: their failure is wholly attributable to the obstacles which beset them, both public and private; and until these are removed, it is in vain to expect perfection, or even a partial fulfilment of the duties required from engines for such purposes.

A select committee of the House of Commons were appointed to investigate and report upon the subject of steam carriages, (road locomotives) in the year 1831, and, after examining several eminent engineers, came to the following conclusion:—

"That sufficient evidence has been adduced to convince your Committee,—

"1. That carriages can be propelled by steam on common roads at an average rate of 10 miles per hour.

"2. That, at this rate, they have conveyed upwards of 14 passengers.

"3. That their weight, including engine, fuel, water, and attendants, may be under 3 tons.

"4. That they can ascend and descend hills of considerable inclination with facility and safety.

"5. That they are perfectly safe for passengers.

"6. That they are not (or need not be, if properly constructed) nuisances to the public.

"7. That they will become a speedier and cheaper mode of conveyance than carriages drawn by horses.

"8. That, as they admit of greater breadth of tire than other carriages, and as the roads are not acted on so injuriously as by the feet of horses in common draught, such carriages will cause less wear of roads than coaches drawn by horses.

"9. That rates of toll have been imposed on steam carriages, which would prohibit their being used on several lines of road, were such charges permitted to remain unaltered."

LODE (in mining), a vein containing metal.—*See Mine and Copper-mine.*

LOW PRESSURE, or CONDENSING ENGINE, a steam-engine, in the cylinder of which a vacuum is formed, whereby the pistons are worked; they are considered to be the most economic for ordinary purposes, and are, therefore, in very general use.—*See Steam-Engine.*

MACHINE, an instrument employed to regulate motion, or to increase either its velocity, or its force, the term is, therefore, more particularly significant of the contrivance interposing between the natural force and that employed in fulfilling the end desired, as to a water-wheel which is situated between the water and the apparatus for grinding corn, or for pumping water, as the case may be. The tackle connected with most contrivances are also known by the general name of *machinery*. It is a general axiom in mechanics, that whatever a machine may gain in velocity, it loses in force; and, *vice versa*, no instrument effecting a saving in both time and force.—*See Mechanical Powers.*

MARINE ENGINE.—*See Steam-Engine.*

MASONRY, a term applied to all works, either prepared or executed in stone.

It may be classified generally under three heads; viz., 1st, plane ashlar, or cut masonry; 2nd, hammer-dressed masonry; and, 3rd, rubble or rough masonry; and there are several varieties of each practised in different parts of the country. *Ashlar masonry* consists of fair cut stones, and is mostly used for the faces of buildings, when it is well bonded and crumped together; but ashlar for engineering purposes is generally laid solid throughout, particularly where great strength is required.

The cutting or working upon the several faces and beds of stones is called dressing, and such stones are described as *wrought.* The term *hammer-dressed* is applied to masonry, when merely squared and picked by the hammer, and this is more particularly adapted for hard stones. *Tooled,* or *droved,* is another very general description of dressing for hard stones, the surfaces being worked in parallel perpendicular flutes: when the tooling is worked irregularly, it is described as *random tooled;* when on the contrary, they are worked by a chisel or narrow tool, it is called *boasted,* or *chiseled;* the surface is also sometimes nicked or cut with a small tool, when it is said to be *pointed.*

Rubble masonry is composed of stones merely axed on the face, and laid according to circumstances; thorough stones being occasionally introduced.

Brickwork is sometimes brought under this head, being described as *brick masonry.—See Ashlar, Rubble-work, and Pinning-in.*

MECHANICAL POWER, the term applied to the force produced by any machine for the accomplishment of any particular purpose. It may be said to form the measure of all other forces, as it bears reference to the degree of power exerted or required; thus, steam, water, man, and horse power, are all represented by certain amounts of "mechanical power."—*See Animal Power and Horse Power.*

MECHANICAL POWERS, the simple agents employed in producing mechanical power, of which all machines are composed; the application of them constituting the science of "Mechanics."

The mechanical powers are usually divided into six classes; viz., the lever, the wheel and axle, the pulley, the inclined plane, the wedge, and the screw.

METALLING.—*See Ballasting.*

MILE, a land measure of distance, extending 1760 yards: 80 chains also make one mile.

MILL, a machine employed in pulverizing any substance, as that of grain, whereby it is formed into flour, which is usually

accomplished by rubbing it between two hard substances, consisting generally of stone, and termed *mill-stones;* the operation being effected by the aid of machinery.

All descriptions of wheel-work at the present time are known by the general name of *mill-work,* originating, no doubt, from the circumstance of this being one of its first applications.

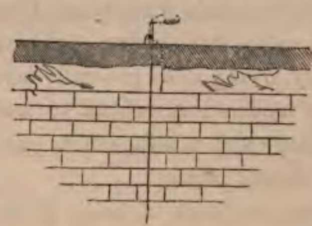
MINE, a term applied generally to underground works, or excavations, when made for the purpose of obtaining metallic ores, and other minerals.

The body of the earth, as far as investigated, consists of numerous strata, or beds, of various substances, differing exceed ingly from each other in their appearance, specific gravity, chemical qualities, &c., and the strata of the same district frequently varies considerably at very short distances; the same description of stratum also sometimes occurs in countries far apart. The strata are traversed in all directions by cracks, or fissures, which are supposed to have been originally open chasms, but which are now mostly filled by substances differing from that of the accompanying rocks: when they contain minerals, or any kind of metal, they are called *metallic veins, lodes,* or *courses,* which are only met with in what are denominated *primitive rocks,* as granite and slate, and they are usually found in a slanting position, running from east to west, and of various thicknesses and extent. When a vein runs of an uniform thickness, and in a straight line, it is called a *rake;* if its course is extended and swelled out in some places, and contracted in others, it is termed a *pipe vein,* the wider parts of the vein being termed *floors;* the vein is sometimes divided into branches, when it is said to *take horse:* in some cases a cross grain occurs, throwing it 10 or 20 feet out of its course, by lifting or heaving a portion of it up; and a vein is sometimes run to a mere thread, and at length completely lost, appearing again at a distance. When a vein falls, it is said to *dip,* the reverse being called the *rise.* The miners apply the name of *passable metals* to any soft easy materials, as free-stone, and the like; and when a stratum lies in an inclined position, and ulti-

mately terminates at the surface, it is said to *crop out*. It is rather remarkable, that a less quantity of water is encountered in mines under the sea than in ordinary excavations. There are coal-mines extending for miles under the sea along the coast, which are perfectly dry.

Transverse Section.

Longitudinal Section of a Metal Mine.



The perpendicular line shows the shaft, and the inclined lines (in transverse section) the metallic lode; the several horizontal lines being the galleries. The adit is represented by the level line at the upper part of the cuts.

Mines are entered by three different methods, viz.—1st, by vertical shafts or pits, similar to wells; 2ndly, by day-levels, or adits, which are galleries carried from the side of a valley into the mine; and, 3rdly, by inclined planes, or rather inclined tunnels, from the natural surface into the mine, which is a medium between the two former: they are generally laid with rails, and are sometimes very steep, being worked by water-wheels, or steam-engines. The working of mines was conducted originally in a very simple manner; and only such of the ore that could be easily removed was regarded. Tin is the first metal recorded by historians as having been worked in this country, which probably occurred from its near connection with the surface of the earth. The ore is seldom found pure, although gold, silver, copper, and other comparatively soft metals are frequently met with in a state of purity; it is therefore probable that they were sought for and discovered before iron. Doubtless, but iron, which is a very

plentiful metal, was also worked very early, although it very rarely occurs in a pure state. The vast mountains of metallic ashes and cinders in the neighbourhood of Ashton, near Birmingham, and other places, are supposed to be of very ancient origin, and to have been deposited from the earliest period of civilization in this country. Lead was also early discovered from its striking appearance, and its laying near the surface. Copper is comparatively of modern discovery in this country, not having been worked longer than a century, owing to its generally laying at a greater depth than tin, which rendered it difficult to reach without the aid of proper machinery and tackle, which was not obtained until a comparatively recent period.

Strata, or beds of coal, of the best quality, are extremely plentiful in this country, more so than in any other part of the globe; and it is to this circumstance, that our great advance over other countries in the manufacturing arts is to be traced and ascribed.—*See Coal Mine, Copper Mine, &c.*

MITRE, the diagonal juncture of two substances, as of wood, stone, &c.

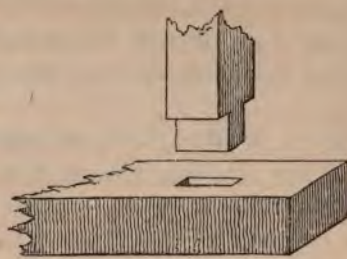
MITRE DRAINS, or CROSS MITRE DRAINS, the drains laid within the metalling of roads to convey the water to the side drains; they are usually placed about 60 feet apart, and filled up loosely with flints.

MITRE SILL —*See Lock.*

MOLE.—*See Breakwater.*

MORTAR, a cement used for building purposes, composed of lime, sharp coarse sand, and the hair of cattle, which should be thoroughly mixed together in a pug-mill, with a small portion of water, in the proportion of 1 of lime to 2 of sand, and well chafed: the lime ought to be used as fresh as possible, and should be kept under an enclosed shed; it should also be employed as stiff as practicable, and the bricks or stones well saturated with water, if possible, particularly in hot weather.—*See Lime, Brick, &c.*

MORTICE AND TENON, a description of joint used in wood-



work. The extremity of one piece of timber is let into the face of another piece, a tongue being formed at the end of the piece to be let in, which is called a *tenon*, and the hole cut in the face of the other is termed a *mortice*.

NATURAL or QUARRY BEDS (of stone), the position in which the laminæ lays in the quarries. It is highly necessary that all stone, particularly soft freestone, should be laid upon the walls in its natural, or quarry bed, parallel with the horizon; when a stone is enclosed on each side, it may be set with its laminæ perpendicular to the face of the wall, as it cannot then flake off through exposure to the atmosphere or frost.

NAVIGATORS, the name given to men working upon canals, railways, &c. A tall man is considered to be worth more wages than a short one, inasmuch as he possesses a greater length of leverage.

NON-CONDENSING ENGINE—*See High Pressure Engine.*

NUT (of a screw), a piece of iron used in connection with a bolt, which is pierced with a cylindrical hollow, throughout which a spiral groove is formed, corresponding with the worm on the end of the bolt.

The nut is screwed upon the end of the bolt, upon the latter being passed through the bodies to be held together.—*See Bolt.*

OBLIQUE ARCH (commonly called *skew arch*), a brick in which the arch is formed aslant.

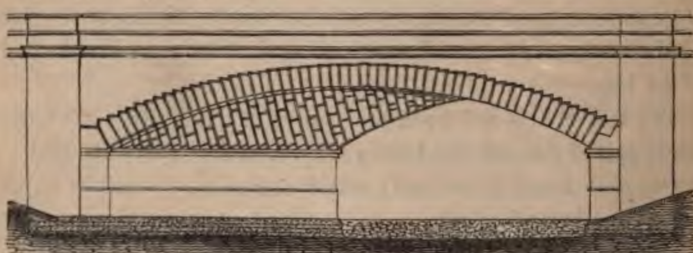
It is necessary, in some situations, for one line of communication to cross another in an oblique direction, on account of circumstances preventing the diversion of either, or of their being set at right angles with each other; the arch of the bridge is therefore obliged to be formed askew, according to the angle of the crossing. The beds of the courses of an oblique arch consist of spiral lines, wound round a cylinder, every part of which

cuts the axis at a different angle, the angle being greatest at the key-stone and least at the springing; and when so placed, and viewed from beneath, they present the appearance of straight lines.

Mr. G. W. Buck, C. E., was among the first who overcame the difficulties attending them in a satisfactory manner. The skew arch, constructed by him, over the turnpike road, at Watford, on the London and Birmingham Railway, is an excellent model. In bridges of very great obliquity Mr. Buck cuts off the acute quoins of the abutments, gradually diminishing the edges of the arch to the obtuse angles on the opposite sides, which is advantageous both in point of appearance and stability.

Elliptical arches are the least suitable for an oblique plan, as the spiral courses render them insecure and difficult to construct; they are also more expensive than the cylindrical. The difficulty of turning skew arches also increases from 90° to 45°, which is supposed to be the most unsafe angle for a semicircular arch; the danger is less from 45° downwards, and they may be safely built at an angle of 25° nearly.

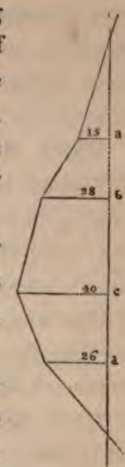
The following cut represents a bridge with an oblique arch formed with spiral courses:—



Offset, a ledge left at the junction of two different thicknesses of a wall, being the upper surface of the lower portion; the upper part of a wall being always less in thickness than the lower.

Offsets (in surveying), the several distances set off from an

imaginary right line, or otherwise, and run along the side of a fence or boundary, for the purpose of measuring the situation of the bends; thus, in the annexed sketch, *a b c d* are the offsets required, which are plotted perpendicular to the principal line, and are usually taken with an offset staff or cross.



OFFSET STAFF, a rod employed in surveying, for measuring short distances; the most convenient length for which is 10 links of the chain, or 6 feet 7.2 inches.

OPTICAL SQUARE, an instrument used in surveying, for laying out perpendicular lines. It is made of brass, in the shape of a circular box, and contains the two principal glasses of the sextant, viz., the index and horizon glasses, fixed at an angle of 45°; therefore, while viewing an object by direct vision, any other forming a right angle with it, will appear, by reflection, at the spot where the observer is situated. This contrivance has almost completely superseded the use of the surveying cross.

PADDLE or CLOUGH a panel made to fit the openings left in lock gates and sluices, for the purpose of letting the water in or out, as may be desired.

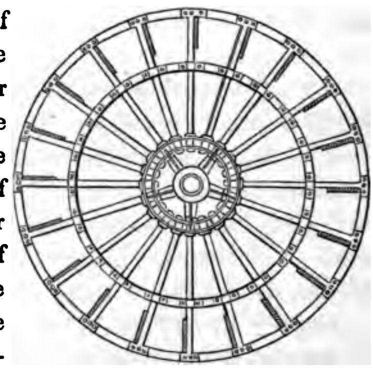
PADDLE HOLES (sometimes called clough arches). The small culverts or drains connected with canal work—as the small passages through which the water passes from the upper pond of a canal into the lock chamber during the process of filling, and through which it again escapes—which vary according to the construction of the locks.—*See Lock.*

PADDLE-WHEELS, the wheels employed in the propulsion of steam-boats.

Common paddle-wheels mostly consist of iron framing, supporting paddle-boards or floats fixed at equal distances around the rim, and radiating from the centre; they are placed one upon each side of the vessel, and are secured to a strong shaft pass-

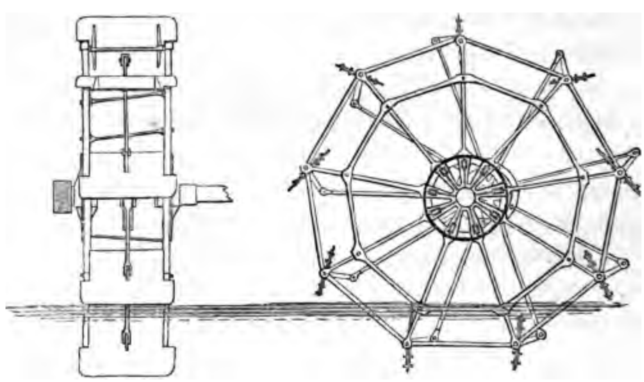
ing across it, which is turned round by the engines, each engine working a crank fixed upon it; and are placed at right angles to each other. The accompanying cut represents the common paddle-wheel:

Common Paddle-Wheel.



There is a loss of power attending this description of wheel, on account of only one of the floats striking the water in a vertical position at the same time, the action of the others being oblique; some of them, in fact, backwater, or partially oppose the motion of the vessel. Attempts have been made to obviate these defects by constructing improved wheels, the paddles of which maintain a vertical position in their passage through the water, when in front of the wheel, by having feathering floats, and these are called ***vertical paddle-wheels;*** and have been found to answer very well for sea-going

Vertical Wheel of the "Medea."

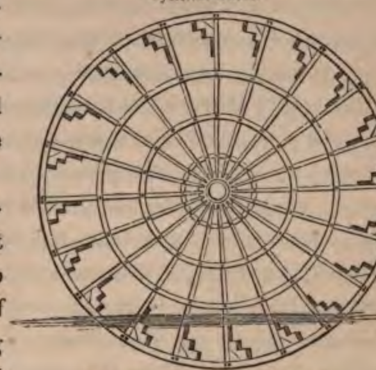


Section. Elevation.

packets, where the paddle-wheels are deeply immersed in the water; but they are more liable to derangement than the ordi-

nary wheels; the floats may be made to leave the water at any required angle. Mr. P. W. Barlow, C. E., states the proportion of the power expended on Morgan's vertical wheels at 546, and of the former at 151 to 197.

Cycloidal Wheel.



Paddle-Wheel of the "Great Western."

The Cycloidal paddle-wheel forms the most recent improvement, and is said to possess the advantages of each of the former, being effective and strong, yet simple, in point of construction. It was patented by Mr. Galloway in the year 1835, although first used by Mr. Field in 1833. The floats are divided into a number of parts, which are placed upon the wheel in the curve of a cycloid, so that they enter the water at the same spot, and follow one another so rapidly as to cause little resistance to the engine; in passing the centre, there is full scope to their action, and in coming out they allow the water to escape readily from them. The Great Western steam ship is fitted with wheels of this description, by Messrs. Maudsley and Field.

The draught of the vessel is necessarily greatest at the commencement of a voyage, particularly if it should be a long one, on account of the full quantity of coals for the whole voyage increasing the amount of tonnage, and other similar contingencies; the wheels are, therefore, immersed very deep in the water, which has the effect of increasing the resistance; but this loss of power diminishes as the vessel proceeds. The adjusting of the floats of paddle-wheels to the requisite depth of immersion is called *reefing the floats*, and there is some difficulty connected with it; but this defect may be partly rectified with the cycloidal wheels, as the outer floats need not be fixed at starting, but fitted on as the voyage proceeds; and the larger the

wheel, the less will the vessel be affected by this defect, as the diameter of the wheel increases in a greater proportion than the variation of immersion of the vessel, the latter is consequently proportionately less than other vessels, when each are laden.

PARALLEL MOTION, an arrangement of parallel rods connected with the piston-rod of a steam-engine and the working beam, by which the motion of the piston is transmitted to the latter: this system is employed in all double acting steam-engines; but a chain was used to pull down the beam in single acting engines. The parallel motions of marine engines are situated below the cylinders, the beams being at the bottom part of the engine.—*See Steam-Engine and Steam-Boat.*

PARALLEL RAIL.—*See Edge Rail.*

PARAPET, a slight wall carried up on the outer faces of bridges, quays, &c., and generally built breast high (or from about 3 feet 3 inches to 4 feet), to prevent accidents to passengers and to the vehicles, by falling off; cast-iron railing and wooden fencing are sometimes substituted for parapet walls.

PASSING PLACE.—*See Siding.*

PAVED CROSSING.—*See Level Crossing.*

PAVED-WAYS, a certain description of tramway, but formed of stone instead of iron; it may be described as a medium between a road and a railway.

Paved-ways possess great advantages over roads—the employment of separate bodies for the wheels of the carriages to run upon, constituting a great improvement; a rough surface is thus obtained for the horsepath, and a smooth hard surface for the carriage-wheels, they are therefore very suitable for ordinary purposes; they also afford a great benefit from their surface being even with the road, and unencumbered with ledges of any kind, by which they are available for carriages of any gauge, or width, between the wheels, which advantage is not possessed by either tramways or railways. The friction upon paved-ways is certainly much greater than with the former; but the resistance operates beneficially in other respects, by offering a greater amount of adhesion to the wheels

of the carriages. A locomotive cannot work usefully on a railway of very steep inclinations; thus, upon 1 in 15, or 20, it can barely propel itself, supposing it worked in the usual manner, or by the adhesion of the wheels only, whereas it could work very easily at these inclinations on a paved-way. Mr. Wood, in his Practical Treatise on Railroads, states, that an engine, drawing 67.25 tons on a level, will only draw 15.21 tons up a rise of 1 in 100 even with the adhesion of all four wheels. Therefore, as steep inclinations are not very objectionable upon paved-ways, it becomes a question whether the present turnpike roads might not be converted into paved-ways, by having blocks of stone laid along them, which would be a ready plan of forming them, and they might be used by both locomotives and horses; or a portion could be railed off, for the exclusive use of the former, by which all danger of coalition, and the like, would be avoided; and this part of the road would not sustain any injury from the feet of horses and other cattle.

The expense of forming a paved-way has been estimated as follows:—

	£	s.	d.
First cost, per superficial yard	0	13	0
Ten years' repair, at 4*d.* per ditto	0	3	4
Ten years' cleansing, at 3*d.* per ditto . . .	0	2	6
	0	18	10
Deduct value of old stone	0	8	0
Per yard, in ten years	0	10	10

Most of the London pavement appears to be laid down at an expense of 7*s.* to 10*s.* per yard.

The paved-way along the Commercial-road, London, is formed of blocks of granite, 16 inches wide, and 12 inches thick, which are laid in 5 and 6 feet lengths, the space between them being filled in with stone paving. The friction upon this road, when first opened, in good order and free from dust, (as dust increases

the friction upon tram-ways and paved-ways considerably, viz., from $\frac{1}{4}$th to $\frac{1}{5}$th) did not amount to more than $12\frac{5}{10}$th per ton, or the $\frac{1}{180}$th part of the load; but the waggons having since created ruts on the surface of the blocks, it has consequently increased. Mr. Walker, under whose direction the way was formed, states the annual maintenance and repair of it at £5 per annum, taking a period of five years, and the cost was $\frac{5}{10}$th cheaper than that of any railway. It must not be forgotten that the above calculation of the friction was made when the stones were newly laid, free from dust, and in a high state of perfection, which it has since lost—the wear of a paved-way being very irregular; and in reference to the repairs upon same, it may also be remarked, that the line has merely been kept in order, not restored to its original state, as is usually the case with railway repairs.

Paving, a covering of stones laid or spread over roads; the flat paving laid down on the footpaths being generally termed *flagging*, or *pavement*, and a curb is placed between them, which keeps each in its place.

The paving in common use consists of square cut stones, mostly granite, and they are set in rows running across the road; and the system of laying them down in diagonal lines, as lately practised, is considered an improvement. There are two descriptions of stone paving employed for causeways: 1st, *rubble causeway*, which is the cheapest, the stones being only slightly hammer-dressed; 2nd, *aisler causeway*, the stones of which are properly jointed and fitted, and are from 8 to 12 inches long, 5 to 7 inches wide, and 12 inches in depth. A paved-way may also be described as a description of aisler causeway.

The experiment of wooden pavement has been lately tried in this country, and with various success, but it is impossible to judge of its merits, at present, any more than in a general way; the wear, however, may be reasonably expected to be less than that of stone, although it is the dearest, in the first instance: the blocks are formed polygonal, and laid upon a bed of concrete, or asphaltum. The system is said to have succeeded very well abroad,

and there is one great advantage connected with it, viz., the absence of all noise. The blocks laid down in the Old Bailey, London, are hexagonal prisms, varying from $8\frac{1}{2}$ to $9\frac{3}{8}$ inches long.

Penstock, a sluice or floodgate employed to retain the water of a mill-pond, water-trough of a water-wheel, &c., and to let it off when required.

Pentagraph, an instrument used for reducing or for enlarging plans.

Perbend, or Thorough, the term applied to the heading stones forming a wall, when they are carried through the whole thickness: if the stones only reach a part of the way through, they are termed *binders*.

Perpendicular Lift (on canals), a contrivance for passing the boats from one level to another.

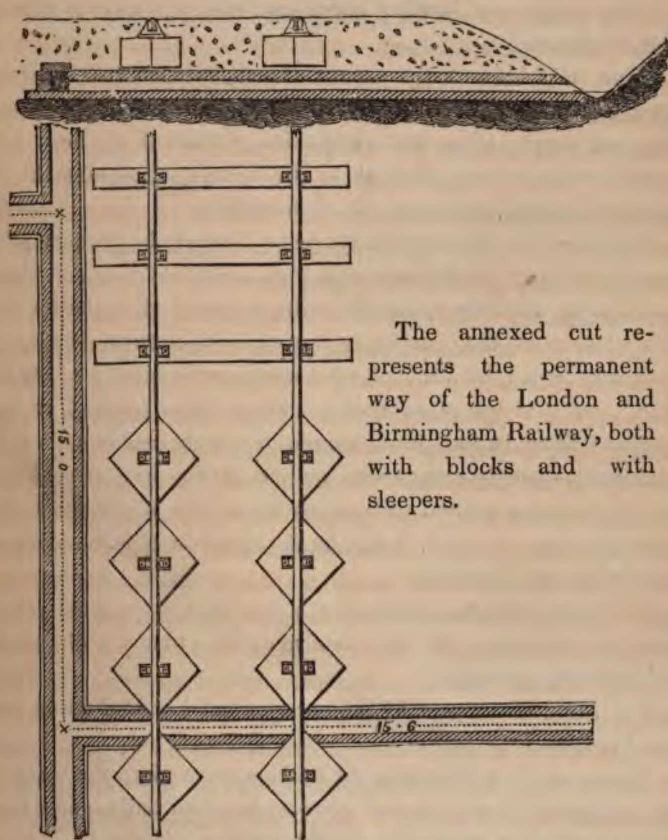
The perpendicular lifts on the Grand Western Canal, by Mr. James Green, C.E., have deservedly attracted much attention; they are intended to remedy the scarcity of water on that canal, by overcoming a great height at one spot, one of them having a 46 feet lift: this lift consists of parallel chambers, somewhat similar to those of the common lock, a pier of masonry being carried up between them; and a wooden water-tight cradle or cistern, is fitted into each chamber, for the reception of the boats; the boats carry about 8 tons, and are 26 feet long and $6\frac{1}{2}$ wide, drawing 2 feet 3 inches of water (whereby a canal 3 feet deep is sufficient for them), and the water is kept in both the upper and lower ponds by lift-up or stop-gates. Upon one of the cradles reaching the upper gate, it is secured to it water-tight, by a bolt and staple, and the doors of both the canal and cradle are drawn up together by a winch gear fixed on the side of the chamber: after sufficient water has escaped into the cradle, to cause its descent, the doors are let down, and the cradle is allowed to descend to the lower level, where it rests upon cross-beams, when, by a contrivance, it is forced close to the lower stop-gate of the canal, and rendered water-tight as before; the lower gates are then raised, and the boat floated out: three

sheaves, each 16 feet diameter, are fixed at the top of the chamber, for the purpose of raising and lowering the cradle, the shaft attached to same being supported by iron framing and columns; the two outer sheaves simply support the chains, but the centre one has a spur gear, in segments, fixed to it, which works on pinions on each side, thereby giving motion to bevel gear, and diagonal shafts, by which a communication is effected with hand winches fixed on each side of the chamber, when required; thus, the machinery may be put in motion by these winches, as well as by the gravity of the cradles; and a brake is also attached to each of them, for regulating the descent of the cradles: a strong iron bar is fixed at the top of each cradle to which the suspending chains are attached; which latter pass over the sheaves, and the cradles are kept in a horizontal position, by means of an adjusting rod placed above them, in a horizontal position, to which they are screwed up, as may be required. The length of the suspending chains are so arranged, that when one cradle is at its proper level at the bottom of the lift, the other is in a suitable position at the top; and no more force is required to put the machinery in motion than the power to overcome the *vis inertiæ* and friction of the apparatus, which is obtained by making the length of the chain a trifle shorter than the height of the lift, say about 2 inches, which produces a preponderate weight in the descending cradle of about 1 ton; a sufficient space is left at the bottom of the chamber to allow of the coil of the balance-chains, which are fixed beneath them, by which the cradles are equipoised at whatever height they may be, and a drain is laid from each: the side and cross walls of the chambers are pierced by arches, which give light below, and afford access to the several parts. The quantity of water consumed is about 2 tons for about 8 tons of cargo; whereas, in common locks, it is about 3 tons of water to 1 ton of cargo.

PERMANENT WAY, the finished road of a railway. The term is applied in contradistinction to the *temporary way* laid down for the purpose of forming the line: the term is usually understood

to refer to the rails, ballasting, spiking down of the chairs to the blocks, and fastening of the rails to same; also adjusting the gauge of way to the proper level and curve. The permanent rails are elevated above the surface of the ballasting rather more than an inch.—*See Railway and Ballasting.*

Transverse Section, showing one side only.



The annexed cut represents the permanent way of the London and Birmingham Railway, both with blocks and with sleepers.

Plan, showing one side only.

PIER, a strong marine erection, commencing from the shore a rocky point being preferred) and jutting into the sea, extending

either in a curved or in a straight line, constituting a harbour for the protection of shipping and other craft. Piers are generally constructed of strong masonry, with fender piles and framing: iron is also adopted in some cases, after the suspension principle, such being called *chain piers*; and timber piers of slight construction, termed *jetties*, are sometimes erected, which are employed merely for the purpose of landing goods and passengers.—*See Harbour and Breakwater.*

PIER (of a bridge), the impost or wall from which the arches spring or abut. The thickness of the upper part of the piers of bridges, appears, from the examination of some of the most celebrated works, to vary from $\frac{1}{7}$th to $\frac{1}{8}$th of the span of the arch; the piers of Neuilly Bridge are $\frac{1}{9}$th of the span.

The piers of wooden bridges were formerly built upon piles, termed *stilts*, in situations where they could not be laid dry, at the bottom of the river, and the stilts were cut off at the level of low water-mark, the piers being carried up upon them; they were also surrounded by a row of piles which were placed a few feet from them, and the place enclosed was called a *starling*, or *jetty*, and was filled in with loose stones, or rough rubble work; the arches were mostly commenced on the paving laid on the top of the piles. This method of erecting a pier was afterwards superseded by caissons; and, lastly, by the adoption of coffer-dams.—*See Caisson and Coffer-dam.*

PIER (in buildings generally), a flat buttress projecting from the face of a wall; the term is also applied to any wall situated between two openings.

PIG IRON, also known by the name of cast-iron and crude-iron. *See Pig Iron.*

PILES, or PILE TIMBERS, the timbers driven into the earth for the support of structures and other works, when built upon a loose soil, whereby the foundation is rendered firm and stable.

Buildings erected on marshy soils are frequently rested upon piles, which are mostly of round timber, and from 9 to 18 inches diameter, and placed about 2 feet apart, which are driven home

into some solid stratum, passing completely through the loose earth, or upper stratum. The feet of the piles are generally provided with wrought-iron shoes, weighing from about 8 to 25lb. each, and the heads are enclosed by strong iron hooping, to prevent their splitting in driving; although they are sometimes driven without any: but a flat piece of wood, or a plate of iron, is placed on the head of the pile which receives the ram at the end ofeac h stroke,instead of the pile. Amsterdam and other cities are built wholly upon piles

The stoppage of Dagenham Breach, on the River Thames, by Captain Perry, about the year 1720 was accomplished by piles morticed into one another by a dovetailed joint.

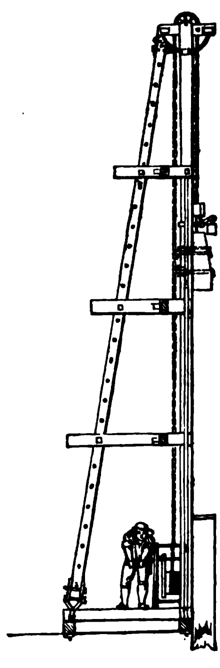
The foundations of walls are sometimes enclosed by square, or edge piles, termed *sheet piling*, which are driven close together: they are more especially employed in works adjacent to the sea, and to rivers, marshes, &c., whereby the soil is prevented sinking by forcing out in a lateral direction.

PILE-DRIVING MACHINE, a machine used for driving piles into the ground, consisting of a strong framework.

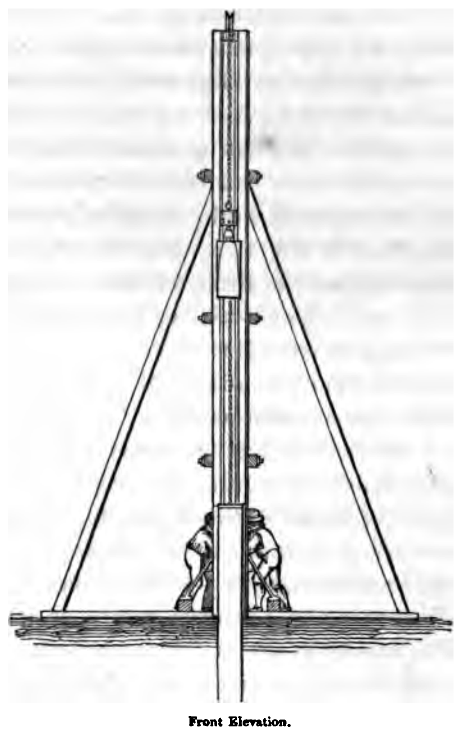
The pile-driving machine usually employed at the present time is composed of two pieces of wood, about 30 or 35 feet long, which are placed in an upright position, and rested upon sill-pieces, the space between them forming a slide or gauge for the iron ram to be drawn up and run down; the slides are edged with iron, a strong shoring-piece is secured upon each side, and a ladder is also connected with them, in the opposite direction, with horizontal ties at different heights; and the whole is further secured by stays and chains at different parts. There are two cross-pieces laid across the sills, upon which a crab is placed, by which the ram is drawn up; there is, an apparatus situated immediately above the latter, usually called a *monkey*, for disengaging and again securing the ram after each fall, a chain being attached to it, which is carried over a pulley ! fixed at the top of the framing, and passed down again on the other side to the crab. The length of the fall of the ram is regulated

at pleasure by a rope fastened to the monkey, which allows of its moving upwards to a certain extent, when its disengagement from the ram is effected: a pair of forceps, or tongs, have also been extensively used for detaching the ram.

The accompanying cut represents one of the pile-driving machines used in building the embankment of the New Houses of Parliament:—



Side Elevation.



Front Elevation.

PINION (in mechanics), a small toothed wheel, which drives, or is driven, by a larger one.

PINNING or PINNING IN (in masonry), a system of wedging or underpinning the bed of a stone, and employed when it is not properly squared, to supply any deficiences, and which is consequently a very objectionable practice.

PIPES, the name applied generally to the vessels employed for the conveyance of any fluid, and which are usually of a cylindrical shape.

The pipes used at the present time for water, gas, &c., are mostly formed of cast-iron. Water pipes are cast in lengths of 9 feet, the principal ones being called *mains*, and the others *services*.—*See Water Works and Gas Works.*

PISTON, a thin cylindrical body adapted to move within a cylinder, and employed in steam-engines and pumps, being the body acted upon by the steam or air, as the case may be; it is therefore necessary that it should run up and down as nearly air-tight as possible; they are sometimes formed of wood, with leather belts nailed round the edges, but metal is the material in general use at the present time. Metallic packing is almost exclusively employed for the pistons of steam-engines, instead of leather or hemp coiling; the packing consists of rings possessing a tendency to spring outwards, and they are further kept so by springs within the body or substance of the piston; the metallic packing also presents the least friction, and is the most durable.—*See Steam-Engine and Locomotive Engine.*

PISTON ROD, the rod connected with a piston, being passed through the centre of it, and secured by means of a screw or a key; the other end of the piston rod of an ordinary steam-engine is attached by a joint to the parallel motion, whereby its action is communicated to the working beam. In marine engines it is secured to a cross head at the top, and in locomotive engines to the connecting rod.

PLAN, the name applied to a plot of land, or to a horizontal section of any engineering work.

According to the standing orders of the House of Commons, all plans for railways, &c., are required to be drawn to a scale of not less than 4 inches to a mile, and the enlarged parts to a scale of not less than $\frac{1}{4}$th of an inch to 100 feet.

PLANE, this term, as applied to railways, refers to each length of a line of railway at the same gradient or inclination. They are

of two kinds, *level* and *inclined.—See Gradient, Inclined Plane, Self-acting Inclined Plane, and Stationary Plane.*

PLANE TABLE, an instrument formerly much used in surveying, for taking angles and laying down the work in the field as it was measured. The plane table consists of a board, upon which the paper is laid, and enclosed by a frame, graduated into degrees from the centre, by which the lines can be easily plotted, and a compass is also connected to it.

PLANKING, a term applied to a layer of planks, or to any other timber (excepting fir), when exceeding $1\frac{1}{2}$ inches in thickness.

PLATE RAILWAY.—*See Tram Railway.*

PLOT, a plan, or horizontal section of any land, country, or works.—*See Plan.*

PLOTTING, the operation of laying down the lines of a survey, by admeasurement, from the field-book.

In plotting a survey, it is generally customary to have the north upwards, the writing running from east to west. Upon the first line being drawn in the required direction, the length of the second line is taken as a radius, and a curve described from the second station; another curve is then described from the other end of the first line, after the same system, by which the apex of the survey is found; the adoption of beam compasses for this part of the operation is found very convenient, particularly if the survey is extensive: the tie lines across the survey (*see Surveying*) have next to be tried, and if found correct, the offsets may be laid

off (*see Offsets*), the same system being followed out in the remaining portion of the plan. In plotting a field taken by chain angles, it is usual to set out the angles to a much larger scale than that of the survey, by which a greater degree of accuracy is obtained. All angles taken by angular instruments, as theodolites and sextants, are laid down by circular or semicircular protractors. The whole of the main lines of a survey should be set off before plotting the offsets.

PLUNGER, a long solid brass cylinder, and sometimes employed as the forcer in force pumps.—*See Pump.*

PLUMBER BLOCK, a carriage fastened on to any contrivance, and adapted to support a shaft or axle.

POINTING, a term applied to the finishing of the external face of the several courses of a wall. The common mortar is first scraped out, and the joints and courses cleaned, when they are filled up with fine mortar or Roman cement.

POLINGS, the small boards supporting the earth during the formation of a tunnel.

POST, any piece of timber, when used in an upright position, as a king post, story post, &c.

PORTLAND STONE, a hard white sandstone procured from quarries in the Isle of Portland, and formerly in general use in the metropolis for both engineering and architectural works; but its use in engineering has been much superseded by granite, and in architecture by Gloucestershire stone.

The merchantable beds of this stone are usually covered with a stratum called the *cap*, which is harder than the beds beneath it, and which is generally removed by gunpowder.

PRIMING (in steam-engines), the hot water carried along with the steam from the boiler into the cylinders, which is very objectionable: various methods have therefore been resorted to of getting rid of it.

PRINCIPAL.—*See Roof.*

PRISMATIC SQUARE, an instrument used in surveying for measuring horizontal angles only, and which are taken from the magnetic meridian; a graduated floating card being attached to the needle. This instrument is very well adapted for filling in the detail of a map, being very portable; but all the principal points should be fixed by a theodolite.

PROTRACTOR, a mathematical instrument used for laying down on paper the angles of any figure. The protractors mostly used consists of a small brass semicircle, the ends of the arch being connected by a straight rule, the outside edge of which consti-

tutes the diameter of the outer circle; the semicircle is divided into 180 parts, termed degrees, and represented thus °, as 10°, and there is a small point in the diameter which marks the centre; circular protractors are also much employed, the divisions being numbered from °, 10°, 20°, &c., quite round to 360°, the same as the theodolite, which the protractor represents. Protractors are also made in the form of a parallelogram, and graduated from a centre on the lower edge, which represents the diameter of the circle, to divisions marked off for the degrees.

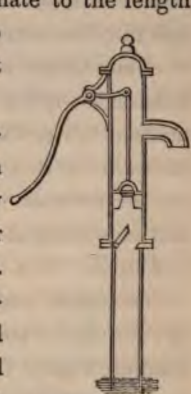
PUDDLE, a mixture of good tempered clay and sand reduced to a semifluid state, and rendered impervious to water by manual labour, as working and chopping it about with spades. It is used for the purpose of retaining the water in any particular situation, or for excluding it from any works: and it is usually spread in layers of about 12 inches in thickness.

PUNNING.—*See Claying.*

PUMP, a machine for raising fluids, by means of pistons, or buckets, working in tubes, valves being also placed within them.

Pumps may be described generally as being of two kinds: 1st, those which operate upon the lifting principle, and termed *lifting pumps;* 2ndly, those of the forcing description, termed *force pumps.* Lifting pumps are applied to wells where the height does not exceed 33 feet, or 30 inches in practice, as in the case of the pump in common use, and known by the name of the *suction pump,* which consists of two tubes; the end of the lower one, termed the *suction pipe,* being placed in the water to be lifted; and the higher tube, called the *barrel,* is furnished with a spout at the top, for the escape of the water, a valve opening upwards being placed at their junction; a piston or bucket is moved up and down the barrel, perfectly air-tight, by means of a lever handle fixed at the top, a valve is also placed in it, opening upwards. Now, as the bucket is moved upwards by the handle, the air below escapes by means of the stop valve, but it cannot again return: the whole of the air is thus removed from the

suction pipe, on the same system as in the air-pump. The length at which the water will rise is proportionate to the length of the stroke of the piston, and it continues to rise higher at each stroke until at length it passes out at the spout.


The Suction Pump.

This description of pump consequently operates by the pressure of the atmosphere from without, which forces the water upwards, by reason of the vacuum formed within it, the air being equal to a column of water 33 feet high. The water may be carried higher by fixing additional tubing at the top of the barrel, and shifting the spout to the upper part of it, and this may be extended to whatever height the force and strength of the pump will admit of; the handle, or prime mover, must also be fixed at the upper end of the delivery pipe, and the piston rod proportionately extended; but this arrangement is unfit for very great depths, in consequence of the bending of the rod, unless cast-iron pipes are employed, when small pieces with projecting arms may be fixed at each joint of the pipe, about 10 or 12 feet apart, to touch the inside of the pipe.

The force pump acts by compression, instead of by exhaustion; and it is mostly employed for great depths, as for mines, also for supplying boilers against the force of steam, &c.; it does not differ much in construction from the former; but no feed or suction-pipe is required, as the barrel extends below the water. The piston works in a frame, *a*, *a*, or some other convenient contrivance; and the water moves upwards at each upstroke through the valve in the top of the piston; the rising pipe *b*, which delivers it, may be continued to any height; the barrel *c*, *c*, is also filled again at each stroke. Force pumps, which take advantage of the pressure of the atmosphere (and most of them do), are called *lift and force* pumps.

The Force Pump.

The Lift and Force Pump.

The accompanying cut represents a lift and force pump, as generally constructed. The feed pipe dips into the water to be raised, and may of course be of any height not exceeding 33 feet; the supply upwards is rendered continuous and regular, by means of an air-chamber *o, o,* the elasticity of the air within it acting upon the surface of the water *(see Air-chamber)*; the barrel is sometimes covered over, a stuffing-box being fixed in it for the piston to slide in.

The length and leverage of a pump is termed the *stroke*; and Mr. Tredgold states, in reference to the pumps employed in draining mines, that the stroke should not exceed 8 feet, and that the velocity of the piston should be no more than 98 times the square root of the length of the stroke. There have also been several attempts made recently to introduce pumps worked by a continuous rotative motion, and with considerable success.—*See Drainage of Mines.*

PURLINE.—*See Roof.*

PUZZOLANA, or POZZOLANA, a celebrated natural cement, formed of volcanic ashes, and of great service in hydraulic works, as a small portion of lime hardens it very quickly, even when applied under water.

QUARRY, an artificial excavation formed in rocks or in rocky ground, for the purpose of obtaining marble, stone, slate, and the like. Blocks of freestone are usually *drawn* from the quarries as follows, the ground is first *uncaped* by removing the soil, and the grain is examined; the direction of the beds of laminæ is called the *cleaving grain,* and those in the contrary direction the *breaking grain;* the quarrymen then drive wedges into the stone in the direction of the cleaving grain, until they loosen the block, they then proceed with the other side, and afterwards with the ends of the blocks; the wedges are driven about 6 or 8 inches apart, and the whole of the wedges on one side are driven at the same moment, the strokes being delivered with exact regularity.

Hard stones are quarried in a somewhat similar manner, viz.,

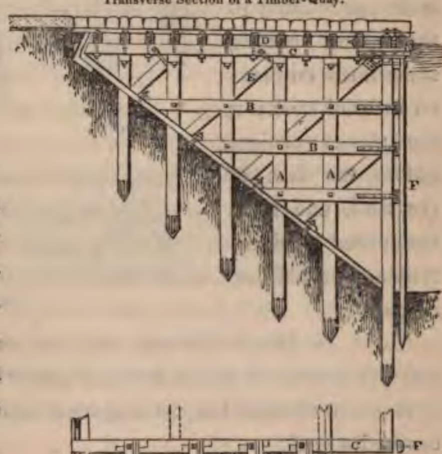
by means of channels, in which wedges are driven, but stronger implements are obliged to be used; iron bars are sometimes employed for confining the wedges in their proper position during the operation. The blocks are also sometimes separated by the aid of gunpowder, the operation being called *blasting*, but a great waste of stone is caused by this plan in consequence of its irregularity. In some quarries the blocks may be obtained of almost any dimensions, while others only furnish blocks of a limited size, owing to the peculiarities of their formation; quarries situated close to the sea, or to rivers and canals, possess great advantages over others, an easy communication thereto being of great importance. The stones quarried for the purposes of building are usually raised and squared out roughly into an even shape, and the builders afterwards cut them to the forms required.

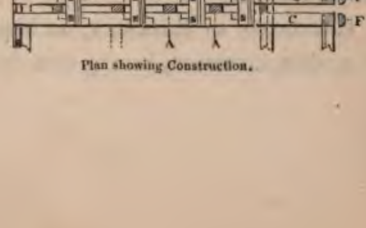
QUEEN, or QUEEN-POST.—*See Roof.*

QUICK LIME.—*See Lime.*

QUAY, or KEY, the name applied to a long wharf by the side of a harbour, river, or canal, for the purpose of landing and shipping goods and passengers, being furnished with cranes and capstans, also mooring posts, rings, &c.

Transverse Section of a Timber-Quay.





Plan showing Construction.

A, A, side piles.
B, B, side wales.
C, C, cross beams.
D, D, top beams.
E, E, side braces.
F, F, fender piles.

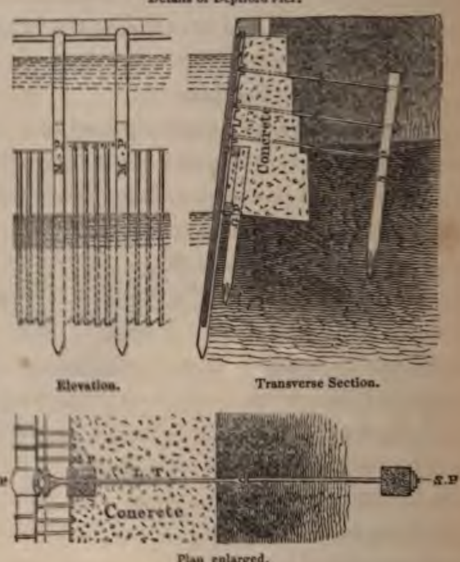
The quays of harbours are generally formed by retaining walls being properly supported by counterforts, and backing fender piles are also fixed in the front to protect them from injury.

Timber is also much employed for this pur-

pose on the banks of rivers; the accompanying sketch *(see Cut on last page)* represents a portion of a timber-quay; no other kind of material is used in America for this purpose, it being very plentiful. The piling in general need not go further into the ground than is sufficient to take a firm hold.

Cast-iron piling has also been very successfully employed for the protection of wharfs, as those recently constructed at Blackwall and Deptford, the main piles being formed with rebates on each side, into which the sheets are driven, and the former are secured at the back by stays and a thick bed of concrete; great care is necessary in driving iron piles on account of their greater liability to fracture, compared with those of timber.

Details of Deptford Pier.



Elevation. Transverse Section.

Plan enlarged.

S, P, stay piles.
M, G, main piles.
G, P, guide piles.
L, T, land ties.

Quoin, the name given to the corners of stone and brick walls, but referring more particularly to the stone edging sometimes employed in brickwork; if the stones project before the face of the wall, and have chamfered edges, they are termed *rustic quoins*.

Race, or Race Course, the cut or canal along which the water is conveyed to and from a water-wheel.

Rack, a straight bar, having teeth or cogs similar to those on a toothed wheel.

Railroad, or Railway, an improved description of roadway, of modern invention, having been used from about the year 1600;

railways or tram-ways, as they were first called, were originally formed of wood, this plan becoming perfected in the *double way*.—*(See Cuts in Tram-way.)*

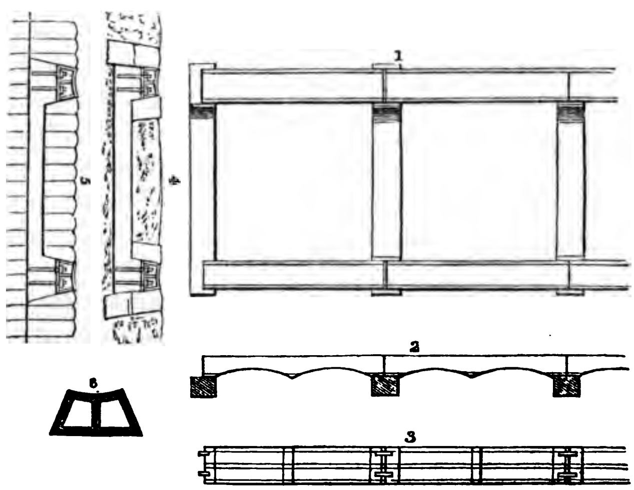
Cast-iron tram-plates were next employed, then wrought-iron, and at length wrought-iron edge rails were adopted; these several description of rails are detailed under the heads of Tram Railway and Edge Railway.

Railways were first used in the collieries, particularly in those of the north of England, and horses were exclusively employed upon them for many years, and very little attention was bestowed upon the gradients or inclinations of the road; the horse was consequently obliged to exert himself according to the utmost of his power for a short distance, after which he might not be required for some time, and it was customary for the men to unhook him and allow him to follow after the waggons, at very rapid descents, where the gravity was sufficient to propel the waggons. Accidents were very common upon these *runs* or inclines, although a brake or convoy was employed to check the waggons, but they were frequently prevented acting in wet or damp weather, owing to their imperfect construction and the steepness of the planes; ashes were sometimes strewed over the rails, to assist the working of the brake, notwithstanding which the works were often stopped; thus, if a sudden shower occurred when a train was descending a very steep plane, it let them down at a fearful velocity, and, despite of ropes which were drawn across the railway to stop them, fatal results sometimes ensued, as the ropes were frequently broken. These early railways generally descended in the direction of the delivery of the goods conveyed upon them; the waggons were, therefore, easily drawn back when emptied. The gross load upon the wooden rails was about 2 or 3 tons, but upon the introduction of iron tram-rails, a horse took nearly double, whereby the velocity of the train down the inclined planes was much increased, which is supposed to have originated the idea of self-acting inclined planes.

There have been many different descriptions of rails proposed at various periods, amongst others was the oval rail, executed on the Penrhyn Railway, by Mr. Wyatt, in the year 1800.

It was about 4 inches deep, and cast in lengths of 4 feet 6 inches, with a plug at each end, which was let into the stone sills, each length weighing 36lbs.; and the wheels run upon these rails had concave rims: but it was found in practice that these rails had a tendency to wear out very quickly, when others were consequently substituted.

Mr. Woodhouse's "Patent Rails," dated 1803, are very ingenious:—*(See Cuts.)*



Details of Woodhouse's "Patent Rails."

Fig. 1, Plan of the rails and sleepers, which are formed of cast-iron.

Fig. 2, Side elevation.

Fig. 3, Plan of a rail inverted.

Fig. 4, Transverse section, showing the mode of securing the rails, the sleepers being bedded in gravel.

Fig. 5, Transverse section, in which both the rails and sleepers are worked in stone paving.

Fig. 6, Section of the rail enlarged.

It may be briefly stated, that wrought-iron parallel edge rails, set on chairs, are now very generally adopted, the weight being about 65 lbs. to the running yard. The system of continuous bearings is also employed on some lines of railway. The steam-engine was applied to railways, shortly after its application to mechanical purposes generally, or about the year 1808, (at which period it was employed in drawing the minerals from the pits); its action was at first applied upon the ascents only, a rope being extended from the steam-engine, and made fast to the waggons, whereby they were drawn up—which system was afterwards introduced upon the remaining portions of the line; and it continued in use until the invention of locomotive engines, which were then run upon the level portions, and the fixed engines were confined to the inclined planes. Horses may be described as preferable to locomotives when the amount of goods to be conveyed is small, and the distance short, particularly if coal is scarce upon the line; and there is another great advantage attending animal power over mechanical, viz., that the degree of force may be varied accordingly as may be required, but, of course, within certain limits. Locomotives are the most suitable where dispatch is required, and the goods to be conveyed are light and valuable; also, where many passengers are expected, and the line is of some length and pretty level; and the system of fixed engines is the best for a hilly country, where the levels do not admit of sufficient adhesion for the wheels of locomotives. The practice of putting two engines to a train is not considered so advantageous as dividing the train into two, and putting an engine to each, as that engine travelling the fastest does the largest proportion of work.

The American railways were originally formed of timber beams, upon which flat iron bars were laid; upon these being found objectionable, on account of their premature decay, stone was used in place of the timber rails; next came heavy iron rails, laid upon

stone blocks, but the great variations of the weather soon deranged this plan: a foundation of timber was then substituted; which is the plan now mostly adopted. The Alleghany Postage Railway, constructed by Mr. Roberts, C. E., in the year 1835, is formed of white oak longitudinal pieces, 10 inches by 10 inches, imbedded in the ground; cross transoms of locust tree, 8 inches by 6 inches, and 7feet 6 inches long, are laid athwart them, notched and trenailed, and upon these the chairs are bolted; the rails are laid about 3 inches to $3\frac{3}{4}$ inches high, and from $3\frac{1}{4}$ inches to $4\frac{1}{4}$ inches on the base.

The resistance to the motion of a carriage upon a railway arises from two causes,—1st, from the friction of the several parts of the machine, as described under the head of Friction; and, 2ndly, from the resistance offered by the air and wind: the atmosphere equally opposes the passage of the stage coach, the track-boat, and the steam-boat; but the motion of these vehicles being comparatively slow, and the power required to overcome the friction encountered being very great, the resistance of the air is disregarded in their construction, but a very large proportion of the resistance upon railways is attributable to it, as the atmospheric resistance is supposed to vary in the square of the velocity; a higher velocity on a railway than 35 miles an hour has therefore been deemed inexpedient with the present engine powers: the expense attending any further increase of speed would also be very great. The average speed of the first class passenger trains upon public lines of railway varies from 20 to 30 miles an hour; there has been a few instances of an engine, with its tender, acquiring a very high velocity—as 15 miles in 15 minutes. The effects of high winds upon a railway train is very considerable, particularly side winds, as they press the flanges of the wheels against the rails, thereby impeding their progress, and increasing the wear and tear much. Public lines of railway, (as the London and Birmingham,) are generally made 33 feet wide in excavations *(see Excavation)*, and 30 feet on embankments *(see Embankment)*, the difference being caused by two drains, each 18 inches wide,

which are required at the bottom of cuttings, one upon each side the line: the surface of the ballasting or road is laid a little convex, to carry off the water; and two or three yards should be allowed on each side for fencing and ditching. The width between the rails is 4 feet 8½ inches upon the principal railways throughout the kingdom, (as the London and Birmingham and Grand Junction Railways—although it is made 7 feet upon the Great Western), and the intermediate space in the centre between the trackways is usually about 6 feet, and it is of similar width as the space between the rails upon some lines—as upon the Newcastle and Carlisle, and the Leeds and Selby Railways; and the side space, or the distance on the outside of the rails, is generally about 5 feet—as upon the London and Birmingham and Grand Junction Railways.

The following table shows the average expense of working the Liverpool and Manchester Railway, from the year 1831 to 1834:—

HEADS OF CHARGE.		Merchandize, per ton per mile.		Passengers.		Aggregate cost, per ton per mile.	
		Useful load or of goods.	Gross load.	Per passenger per mile.	Per ton per mile gross.	Useful load or of goods.	Gross load.
		d.	*d.*	*d.*	*d.*	*d.*	*d.*
* Locomotive power		0.55	0.36	0.27	0.73	0.73	0.51
† Maintenance of railway		0.307	0.233	0.085	0.233	0.307	0.233
Coaching	Upholding carriages	—	—	0.054	0.146	0.082	0.058
	Conducting coaching	—	—	0.104	0.282	0.158	0.111
	Duty on passengers	—	—	0.071	0.216		
Carrying goods	Upholding waggons	0.227	0.159	—	—	0.09 4	0.067
	Conducting traffic	1.08	0.76	—	—	0.463	0.324
General expenses		0.354	0.248	0.091	0.248	0.354	0.248
Total cost		2.518	1.760	0.675	1.855	2.188	1.551

The preceding Table does not include the cost incurred in laying

* The cost of locomotive power differs according to the locality of the railway. The London and Birmingham Railway Company have contracted for their motive power at 0.05*d.* per ton per mile for goods, and 0.25*d.* per mile for passengers.

† The average expense of maintenance was £422. 13*s.* 6*d.* per mile.

down new rails where required, as such contingencies would not be likely to occur on another line, neither the interest paid for capital, or the cost of carriage at each end of the line.

The annual cost of private railways is much less, as will be seen by the following Table—which shows the expense of working a line adapted for the conveyance of heavy goods, or for a mixed traffic, where the latter is such that a maximum effect can be produced in the conveyance of heavy goods, without interruption to the general traffic of the line, and where the goods are generally carried in one direction only, the carriages having to be brought back empty in the other direction—deduced from the cost upon the Stockton and Darlington, the Seaham and Clarence, and other railways :—

HEADS OF CHARGE.	Cost, per ton per mile.	
	Useful load.	Gross load
	d	d.
Locomotive power or haulage	0.380	0.191
Maintenance of railway	0.208	0.104
Upholding waggons, including loading and unloading coals	3.265	0.133
General expenses	0.100	0.051
Total cost	0.953	0.479

The following Table gives the comparative average cost of conveying goods and passengers by locomotive engines on railroads :—

Rate of speed, in miles per hour.	Resistance, per ton in lbs.	Cost of haulage, per ton per mile.	Cost of carriages, per ton per mile.	Cost of conveyance, per ton per mile.	Charges for conveyance, per ton per mile.	Remarks.
		d.	d.	d.	d.	
8	8.5	0.375	0.19	1.065	1.065 1.566	Export coals. Lansdale coals.
12	8.5	0.5	0.227	2.138	3.5	General merchandize.
20	8.5	0.25 per passenger. 1.73 per ton	0.206	0.675 per passenger. 2.855 per ton	1*d.* to 1½*d* per passenger. 12.37 per ton	

Dr. Lardner has lately made some interesting discoveries re-

garding railway constants, which he communicated to the last Sessions of the British Association, held at Birmingham, and which confirmed the opinion that he had given in 1835, before a Committee of the House of Lords, viz., that "a railway laid down with gradients from 16 to 20 feet per mile, would be for all practical purposes nearly, if not altogether, as good as a railway laid down from terminus to terminus upon a dead level," as he considered that a compensating effect would "be produced in descending and ascending the several gradients, and that a variation of speed in the train would be the whole amount of inconvenience which would arise; that the time of performing the journey, and the expenditure of power and maintenance of way would be the same in both cases: and he therefore advised that no considerable capital should be expended in obtaining gradients lower than those abovementioned."

He stated to the meeting, that he had since proved this theory upon the Grand Junction Railway, where he found that the mean speed in ascending and descending to be the same as the usual rate of the same engine upon a level, the difference amounting to no more than the casual variations constantly occurring in the moving power, the surface of the rails, commonly regarded as level, being in reality subject to continual variations of inclinations for short distances. He also stated, that the form of the front of the waggons had no influence upon atmospheric resistance, but by increasing the whole volume of the train a material increase was produced in the resistance of the atmosphere.

The motion of a train down an inclined plane has been generally considered to be uniformly accelerated; *i. e.* an increase of velocity takes place every second of time, being the speed due to the gravity of the plane, and the resistance due to the friction of the carriages only was calculated as being the sole check to the velocity: the effect of the atmosphere, or anything else which might produce a retardation, increasing with the speed, was wholly neglected, being considered of comparatively trifling amount; but the learned Doctor proved by these experiments, that the degree

of acceleration was gradually diminished as it run down the plane, instead of increased. The former theory would certainly hold good if there was no other resistance but that arising from the friction, and the speed would then be diminished by the amount of velocity destroyed by the friction of the train only. Now, as the force of gravity is well known, (also the effect produced by an inclined plane, of given inclination, in diminishing the intensity of same), finding the amount of resistance occasioned by the friction, is consequently an easy calculation, all other resistance being disregarded, or the acceleration due to gravity could be calculated, and the actual acceleration moving down the plane observed, the difference being supposed to give the retarding force due to the resistance.

According to this new theory of Dr. Lardner, if an inclined plane of sufficient length could be attained, the motion of a train would continue to be accelerated until a velocity was acquired, which would produce "a resistance from the air, such as combined with friction, would be equal to the gravitation down the plane;" upon such velocity being obtained, the moving weight being equal to the resisting force, no further acceleration would take place.*

As it was thought that inclined planes of sufficient lengths were not accessible to try the accuracy of this theory, it occurred to the Doctor that the end would be equally attained by starting the train from the top of an inclined plane, at a considerable speed, as the acceleration it would receive while descending, added to the speed with which it started, might be expected to give that velocity at which all increase of speed would cease, and an uniform motion be maintained to the bottom of the plane; and this anticipation was realized by experiments, and an uniform gravitation or velocity was produced, which was regulated by the load; when the latter was increased the velocity was increased,

* The angle of repose upon a railway may be cited as a comparative constant to this, occurring when the gravity of the plane and friction of the load are equal.

its motion being accelerated for a short distance from starting, but at length becoming uniform in every case, the velocity diminishing with the steepness of the plane. It was found that the same general principle applied to trains of whatever magnitude; he also ascertained by these experiments that the common estimate of the resistance upon inclines is erroneous, being taken at the same as the resistance upon the level portions, or about $\frac{1}{250}$th of the load; whereas it was found that the actual resistance at high speeds very considerably increased, compared with it when the motion was slow. The motion of a train for about 100, 200, or 300 yards was found to give a very small degree of resistance, when started with little velocity, viz., from $\frac{1}{400}$th to $\frac{1}{500}$th of the load, thereby showing that the atmosphere was but slightly affected by the same, although it amounted to from $\frac{1}{90}$ to $\frac{1}{100}$th of the load, when the initial motion was very great, the state of the weather and the direction of the wind were also found to influence the motion of the train very considerably; a great portion of the force of the engine is also absorbed by the wheels of the carriages, owing to their velocity and their great number, they may be said to act against the atmosphere, and the air for some distance round them is also affected, and which forms part of the resistance opposed to the moving power. The uniform velocity above described was precisely the same upon the curves as upon the straight parts of the line, the former being of 1 mile radius: the Doctor therefore concludes, that curves of that radius have no perceptible effect upon the resistance. Dr. Lardner described his conclusions to be as follows, reserving to himself the power of modifying them when his experiments shall be all reduced.

1. That the resistance to a railway train, other things being the same, depends on the speed.

2. That at the same speed, the resistance will be in the ratio of the load, if the carriages remain unaltered.

3. That if the number of carriages be increased, the resistance is increased, but not in so great a ratio as the load.

4. That, therefore, the resistance does not, as has been hitherto

supposed, bear an invariable ratio to the load, and *ought not to be expressed at so much per ton.*

5. That the amount of the resistance of ordinary loads carried on railways at the ordinary speeds, more especially of passenger trains, is very much greater than engineers have hitherto supposed.

6. That a considerable, but not exactly ascertained, proportion of this resistance is due to the air.

7. That the shape of the front or hind part of the train has no observable effect on the resistance.

8. That the spaces between the carriages of the train have no observable effect on the resistance.

9. That the train, with the same width of front, suffers increased resistance with the increased bulk or volume of the coaches.

10. That mathematical formulæ, deduced from the supposition that the resistance of railway trains consists of two parts, one proportioned to the load, but independent of the speed, and the other proportional to the square of the speed, have been applied to a limited number of experiments, and have given results in very near accordance, but that the experiment must be further multiplied and varied before safe, exact, and general conclusions can be drawn.

11. That the amount of resistance being so much greater than has been hitherto supposed, and the resistance produced by curves of a mile radius being inappreciable, railways laid down with gradients of from 16 to 20 feet a mile have practically but little disadvantage compared with a dead level; and that curves may be safely made with radii less than a mile; but that further experiments must be made to determine a safe minor limit for the radii of such curves, this principle being understood to be limited in its application to railways intended chiefly for rapid traffic.

Attempts have also been made to introduce a Pneumatic railway. Mr. John Vallence was the first who thought of employing the natural pressure of the atmosphere operating upon a partial vacuum, for the purpose of transporting passengers and goods

from place to place; he proposed having cast-iron cylinders sufficiently large to allow the carriages and passengers to pass through them, which latter were intended to act similar to pistons; he caused a model to be constructed with which very satisfactory experiments were made, but Mr. Henry Pinkus subsequently improved the above plan, by transferring the action of the piston from the inside to the outside of the tubes, a model of which has been lately exhibited, and a company also formed for carrying out the scheme; a guide-carriage is connected with the piston on the outside, and termed the *governor*, which drags the train of carriages along the top of the tube, similar to a locomotive, the tube being from 3 feet to 3 feet 6 inches diameter, with ledges on each side, on which the wheels of the carriages revolve; if the carriages are proposed to be run on rails already laid down, or the power be employed to draw barges, the tubes need not be above 2 feet 10 inches to 2 feet 4 inches diameter, and they would be cast in lengths with regular socket joints. The pistons are intended to be worked and the cylinders exhausted by stationary air-pumps worked by steam-engines, and the distance between the stations would be regulated according to circumstances.—*See Continuous Bearings, Edge-railway, Tram-railway &c.*

Railway.—*See Railroad.*

Railway Link.—*See Draw Link.*

Railway Slide, a contrivance employed on railways, for the purpose of shifting a carriage from one line of rails to another, consisting of a platform running upon wheels, upon which there are two or more pair of rails of similar gauge to those employed on the line; the slide is generally placed at the extremity of the main rails of the line, and it runs transversely across it; upon a carriage being wheeled on to the slide, the latter is moved in the direction of the line of rails to which it is required to be transferred, when it is run off.

Rafters, the beams employed in supporting roofing. Rafters are of two kinds, viz., principal rafters, and common rafters; the first are employed to carry the purlines, and the latter lay above the

purlines, and support the slating or tiling, as the case may be.—*See Roof.*

RATCH, a bar containing angular teeth, into which a paul is dropped to prevent machines from running back.

RATCHET WHEEL, a circular ratch.

RECIPROCATING ENGINE, any steam-engine worked by an alternate rectiliniar motion, and which is effected by means of pistons moving in cylinders.—*See Fly-wheel.*

RECIPROCATING SYSTEM (on a railway,) the reciprocating plan of working railways was introduced by Mr. Benjamin Thompson, in the year 1821, who applied it very successfully. It consists of a succession of stationary steam-engines along the whole line, which are fixed about 1½ miles apart, having ropes from one to the other, rollers are fixed along the line to receive the latter. When a train of carriages leaves a station, it is secured to the rope, and is thereby drawn along the line, in which case the rope is termed the *head rope,* and another is secured to the last waggon, which is called the *tail rope,* which is thus pulled along by the train, upon returning it becomes the head rope, and the former the tail rope, thus alternating to and fro. A railway may be worked by stationary engines, but it does not necessarily follow that it should be upon the reciprocating system; thus the Brunton and Shields Railway has five continuous planes worked by them, but only one can be said to be upon the reciprocating principle; as the loaded waggons run of themselves upon three of the planes by the effect of gravity, the rope being used merely to draw the empty ones back, and upon the remaining plane the rope draws up the loaded waggons, the empty ones returning of themselves; it will therefore be perceived that on the last four places one rope only is used, and the plan pursued appears to be very advantageous.

RESERVOIR, a large pond containing a body of water, and employed as a means of supply for hydraulic works, as for the summit levels of canals, water-wheels, &c.; they are usually formed by means of dams or embankments.

Retaining Wall, a wall used for the support and maintenance of a body of earth, when circumstances render it inexpedient to slope the same gradually down.

Retaining walls are sometimes used where land is valuable, and are battered on the outside face from 1 inch to $1\frac{1}{2}$ inches to the foot; the greatest degree of batter (which is usually curved) being given to the foot of the wall.

Retaining Wall, Lond. and Birm. Railway.

Counterforts are generally carried up at the back of the wall, and piers are placed sometimes on the face of it.—*See Batter.*

Retort.—*See Gasworks.*

Rib, a term applied generally to a girder, but more particularly to an arched beam, as to the segments of a cast-iron bridge.

Rigger.—*See Sheave.*

River, a natural water-channel communicating with the sea. Rivers are formed by the union of springs, brooks, rills, &c., and are the natural channels by which the surplus water of a country is conveyed to the ocean, fertilizing the land, and affording a means of transport by navigation throughout their course; they usually take their rise in elevated situations, at the top of high mountains, where the spring rises, and they receive numerous tributaries in the course of their descent, and at length after numerous meanderings they acquire a considerable width; these springs are generally supposed to arise from the condensation of atmospheric vapours, thawing of ice, snow, &c., and some other natural causes. Alterations frequently occur in the courses of rivers, particularly near their mouths, arising from the force of the current, some parts becoming depressed and others raised. The velocity of a stream is usually greatest at about the middle, both as regards breadth and depth; it is consequently least at the sides and bottom.

In order to insure a proper depth of water for the barges navigating rivers, it is found necessary to preserve them by artificial means, such as by sustaining the banks on each side, (which also

protects the adjacent country from inundation) by removing all shoals and obstructions, and by various other works. If the width of a river be increased beyond its natural limits, or that required for carrying off the various land streams and floods, a reduction in depth will be the natural consequence; if on the contrary, the river is contracted or narrowed, it will acquire in depth what has been taken from it in width; a constant expense is therefore necessary in preserving its navigation. Rivers are sometimes widened for the purpose of facilitating the trade upon them, when every means should be taken to secure sufficient depth, and the nature of the soil, of the bottom and sides, duly considered; also the velocity of the current, and every obstacle interfering with the free tidal flow of the sea-water upwards should be removed, all banks, shoals, and obstructions being cleared away: the current should be carried to the utmost point, by deepening and widening the entrance channel, the water will thus rise higher, and the velocity of the flow and ebb will be increased, whereby the scouring power is made greater, and all the numerous impurities from the sewerage will be carried away; the water will likewise be rendered more pure and wholesome. There is less chance of the banks of a large river being overflowed than those of a small one, as the former may be made with a less slope at the bottom, longitudinally, than the latter, owing to the greater inclination of the water to run off by reason of its increased body.

Mr. Nimmo gives the following data on the subject of the relative inclination of streams necessary to insure the discharge of their waters:—

Large and deep rivers run sufficiently swift, with a fall of about 1 foot per mile, or 1 in 5,000.

Smaller rivers and brooks, ditto, ditto, 2 feet per mile, or 1 in 2,500.

Small brooks hardly keep an open course under 4 feet per mile, or 1 in 1,200.

Ditches and covered drains require at least 8 feet per mile, or 1 in 600; and furroughs of ridges and filled drains require much more.

...ALL.—*See Quay.*

...iron pin used for the purpose of joining two ...on together, as in the formation of boilers; they ...in a red hot state, whereby a very great degree ...is obtained in the joint by their contraction ...a double row of rivets is generally employed ...lar work.

...or COMMON ROAD, an expedient for effecting the con... districts, cities, or towns, forming the most general ...communication.

...rmation of roads was most probably commenced at a very ...iod, being a subject of immense importance. The Ro... ...pear to have been quite aware of the advantages of good ...ome portions of the ancient Roman roads remaining at the ...time; but they were entirely neglected during the ...ages, and it was not until the middle of the last century ...y very great improvement was made in them.

...ancient Roman military roads generally run in direct lines, ...illy ground appears to have been selected in preference to ...vel, for the purpose of commanding the country; towers of ...ce being erected on the several summits. The great desi... ...um in laying out of modern roads is to obtain the most level, ...ther with the shortest line of route; some attention being paid ...the materials afforded by the country for the proposed works. Highways, or national roads, are roads of the first class, and ...omprise the great communications throughout the country; they ...conducted under the direction of the Government or of the ...veral county authorities, and are maintained by tolls levied upon the horses and carriages using them; hence the term "turnpike roads." Parish roads rank next to highways, and are sustained at the expense of the various parishes in which they are situated. Private roads, or the roads belonging to an estate, may be instanced as the next in point of importance; and, lastly, lanes, which may belong to either of the last stated classes.

A road should be raised 3 or 4 feet above the surface of the

ground, in order that it may have the benefit of the sun and wind, also as an allowance for drainage; and it should always have an inclination, longitudinally, from about 1 in 60 to 1 in 100, by which the water will be got rid of; but steep inclinations upon a road impede the passage of the coaches, and are likewise exceedingly dangerous; alternate rises and falls also increase the distance: the inclination of highways should not be less than 1 in 30 in the vicinities of towns under any circumstances, and that of parish roads 1 in 20 to 24. The surface of a road should be formed as smooth as possible, provided it remains hard, as it then offers the least resistance; thus a paved-way forms the nearest approximation to a railway. A road should also be of uniform width throughout, say about 30 feet for highways, although 40, 50, or even 60 feet is not too much for the leading thoroughfares

Transverse section of a Road on Mr. Telford's plan of construction.

Ditto, ditto, a culvert being shown beneath it.

to cities; the surface should also be made of a convex shape, for the purpose of carrying the water off into the side drains at the junction of the footway with the road, and it should be conveyed from thence to the ditches upon each side, by means of culverts; proper mitre drains should also be constructed under the road, *(see Mitre Drains)*, and filled in loosely with large flints or pebbles to carry off the water that percolates through it into the side drains; the latter require to be kept perfectly clear of obstructions, and passed into the natural water-courses of the country.

The centre part of a road is generally metalled, the sides being merely gravelled on the natural subsoil, these portions being sometimes called summer roads; the method of paving the centre part is of great importance, the system practised by the late Mr. Telford on the Holyhead road is generally admitted to be the most correct plan of formation, viz., the laying down of a regular close-set pavement, as a foundation for the road, having the broad part of the stones securely placed on the bottom of the excavation upon which the ballasting was laid, consisting of a coating of broken stones, with a binding gravel covering, the thickness of the whole being from about 6 to 9 inches; the old Roman roads may be described as specimens of this principle of construction, as they were formed upon a bottoming of stone and cement, which is frequently discovered almost as hard as iron, and of very great substance. Gravel concrete is employed for the same purpose, in cases where stone is difficult to obtain, as in the case of the Highgate Archway road, the proportions of which were $\frac{1}{10}$th Roman cement, $\frac{1}{10}$th sand, and $\frac{8}{10}$ths stones, with a covering of broken stone, 3 inches thick; the cost of this road amounted to from 12*s*. to 15*s*. per running yard, the portion of road covered with it being 18 feet wide. Concrete, composed of 4 parts of gravel to 1 of lime, has also been successfully used by Mr. C. Penfold, C. E.; for instance, on the Brixton road, where it is laid 6 inches thick, and extends over one half the width of the road, comprising the centre part, and good hard gravel, or broken stone, is spread over afterwards, in two courses; the

first being laid a few hours after the concrete has been placed on the road. The metalling of a road requires to be removed as it is worn down, and on no account should the vehicles be suffered to be in immediate contact with the concrete; the paths on each side of the road may also be much improved by a similar foundation laid about 2 inches thick.

A macadamised road is generally understood to refer simply to a broken stone road, and which are inferior to roads of the above description, unless the subsoil is of a perfectly unyielding nature; they are probably the cheapest to lay down, but their repairs are far the heaviest.

The following are the principles laid down by Mr. M'Adam for constructing roads:—

"That a foundation or bottoming of large stones is unnecessary and injurious to any kind of subsoil.

"That the maximum strength or depth of metal required for any road is only 10 inches.

"That the duration only, and not the condition of a road, depends upon the quality and nature of the material used.

"That freestone will make as good a road as any other kind of stone.

"That it is no matter whether the substratum be soft or hard."

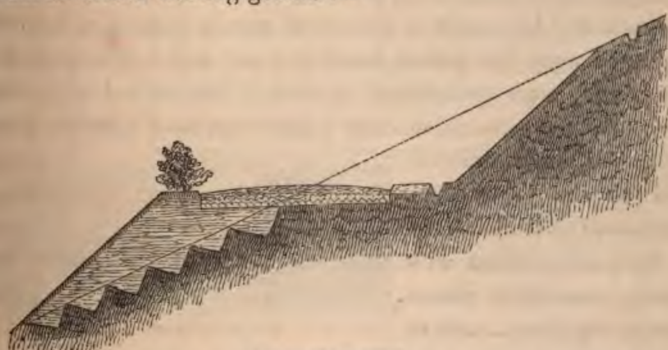
The expence of a Macadamised road has been estimated as follows:—

	£	s.	d.
The first cost per superficial yard	0	7	6
Two coatings, at 1*s.* 9*d.* each per yard per annum, for 3 years	1	15	0
Cleansing, at 10*d.* per yard per annum, for 10 years	0	8	4
	2	10	10

It is now pretty well known that roads so constructed are not fit for situations where there is much traffic, as the expence of keeping them in repair is very great; the continual attrition of the angles of the several stones, from their constantly changing

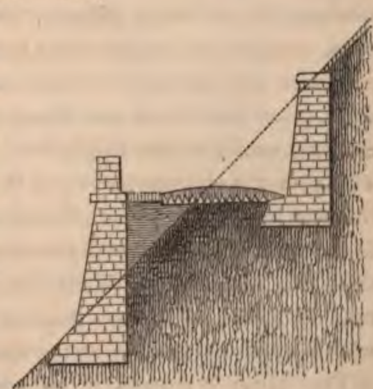
their position, having nothing to support them, is, in fact, much greater than the wear occasioned by the traffic of the road, it is thus rendered dusty in summer, and muddy in winter; hollows are also soon formed by the partial settling of the ground for want of a foundation, whereby the surface is rendered irregular and bad for the passage of carriages.

The following cut represents the method of forming a road on what is termed sideling ground :—



Road on sideling-ground.

Roads are sometimes constructed along rocky ridges, when retaining walls are mostly adopted—thus,



Road on the side of a precipice.

Roads across bogs or moss are formed by first thoroughly draining the ground; longitudinal drains must, of course, extend on each side with other drains parallel to them, also cross drains to carry the water into the side drains; and as this work can only be executed in fine weather, it occupies some time, probably three or four years would elapse before perfectly consolidated; the turf, when thoroughly dried, may be used in forming

the roads and embankments connected with it, being carefully worked in regular layers, and well rolled with a heavy cylinder previous to the gravelling and metalling being laid. The drainage of Chat Moss and Parr Moss on the Liverpool and Manchester railway may be cited as specimens in this class of engineering.

Chat Moss is composed of an extensive bed of peat or turf, about 5 miles in length, and 2 or 3 in breadth (containing about 12 square miles altogether), about $4\frac{1}{2}$ miles of which is crossed by the railway. It consists of a very soft spongy substance, from 10 to 35 feet deep, the bottom being clay and sand. The works for the railway were commenced by cutting longitudinal drains on each side of the line, also cross drains: the moss between these cuts was thus drained, and became partly consolidated: hurdles, 9 by 4 feet, and wattled with heath, were then placed across the line in one or two layers, according to the tenacity of the moss, and a bed of ballasting, 2 feet thick, was laid upon them, upon which longitudinal beams were laid, the timber sleepers being next introduced in the usual manner, and another set of longitudinal ones, upon which the rails were fixed by means of chairs.

A, the Hurdles.

Where the railway is elevated the embankment was formed of dried moss, and it took four times the quantity of material that an embankment of similar height would require, upon sound ground, owing to the sinking nature of the foundation; and where the line was in cutting, it was effected by draining, in a similar manner to the level portions, but by successive lifts or layers, 12 inches thick, the longitudinal ditches becoming deeper every lift. The road is therefore entirely floating upon the moss, and depends wholly upon the tenacity of the materials.

Parr Moss is crossed in embankment, the moss being about 20 feet deep, and the material of an adjoining excavation was used in forming it, consisting of clay and gravel, which gradually sunk

as it was thrown upon the moss; and, although the embankment was only 4 or 5 feet high, at the completion it was found to have

The following table shows the cost of conveying goods and passengers on turnpike roads, with the comparative expence of the same upon railways, both with horses and with locomotive engines.*

Description of traffic.	Rate of travelling, in miles per hour.	Turnpike roads (with Horses).			Railways (with Horses).			Railways (with Locomotives.)			
		Force of traction, in lbs. per ton.	Cost of haulage, per ton per mile.	Cost of conveyance, per mile.	Force of traction, in lbs. per ton.	Cost of haulage, per ton per mile.	Cost of conveyance, per mile.	Rate of travelling, in miles per hour.	Force of traction, in lbs. per ton.	Cost of haulage, per ton per mile.	Cost of conveyance, per mile.
Heavy goods (stage vans)	$2\frac{1}{2}$	73	3*d.*	8*d.* per ton.	8.5	0.56*d.*	1.65*d.* per ton.	8	$8\frac{1}{2}$	0.375*d.*	1.065*d.* per ton
Light goods (vans or light carts)	4	73	4.5*d.*	12*d.* per ton.	8.5	0.9*d.*	$3\frac{6}{27}$*d.* per ton.	12	$8\frac{1}{2}$	0.5*d.*	3.5*d.* per ton.
Passengers and parcels (stage coach)	9	83	0.7*d.* per passenger, 10*d.* per ton.	3*d.* per passenger, 3*s.* per ton.	8.5	0.25*d.* per passenger, 2.24*d.* per ton.	1*d.* to $1\frac{1}{2}$*d.* per passenger, 1*s.* 3*d.* per ton.	20	$8\frac{1}{2}$	0.25*d.* per passenger, 0.73*d.* per ton.	1*d.* to $1\frac{1}{2}$*d.* per passenger, 12.37*d.* per ton

* Arranged from Wood's Practical Treatise on Railways.

taken a sufficient quantity of earth to have formed one 24 or 25 feet high, on ordinary ground; therefore the portion of the line across Chat Moss could not have been made with such materials.

Mr. Macneill stated, in his evidence before a Committee of the House of Commons, in the year 1830, that the expence of improving the present turnpike roads, altering all the slopes to within 1 in 40, would cost from £600 to £2,000 per mile, according to circumstances.

Roads are also sometimes paved, particularly in cities and towns.—*See Paving and Paved Way.*

ROCK.—*See Stone.*

ROLLEY, the name formerly applied to a tram-wheel.

ROMAN CEMENT, a cement in very general use for building purposes, and forming an excellent water cement; being mostly employed with an equal portion of good sharp sand, it also forms a perfect preventive against corrosion, and may therefore be serviceable in covering joints in iron-work, and for similar purposes; the stone is of a dark brown colour, and is principally brought from the Isle of Sheppy.

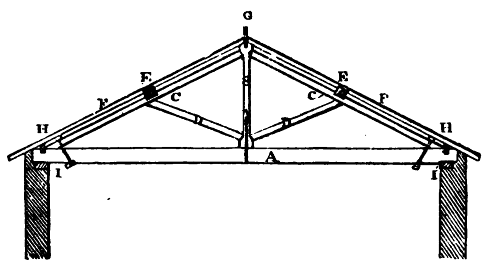
ROOF, the covering to any building or shed.

Roofs may be described generally as being of two kinds, viz., 1st, those with their outer surfaces or tops nearly level, such being usually covered with lead—2ndly, those which have their tops inclined, as the common roof, gutters being formed at their lower edges, and slates employed for the external covering.

In the first description of roof the lead is supported by means of horizontal joists or bearers, proper boarding being interposed between them; and in the second kind, long timbers, called *rafters,* are employed to carry the slates, and either boarding or thin pieces of wood, termed *fillets,* are nailed on them to secure the slates to; when the rafters are long, they are supported by *purlines,* as may be required, and these rest on framed trusses, termed *principals,* which are placed at regular intervals, usually about 10 feet distance; and it is in the construction of these principals

that the stability of the roof mainly depends: such roofs are also described as *trussed roofs*. Roofs of small dimensions are constructed without either principals or purlines. The width between the walls, or supports, is called the *span* of the roof, and the height in the centre the *rise*, the slope of the rafters being termed the *pitch*.

Roofs of from 20 to 30 feet span may be supported by principals, composed of a king-post, principal, rafters, and struts, thus, and of the following scantlings :—



Span in feet.	Tie-beams.	King-post.	Principals.	Struts.
	Ins. Ins.	Ins. Ins.	Ins. Ins.	Ins. Ins.
20	9 × 4	4 × 4	4 × 4	4 × 3
25	10 × 5	5 × 5	5 × 4	5 × 3
30	11 × 6	6 × 6	6 × 4	6 × 3

This and the following Tables are according to Mr. Gwilt, with the exception of the line marked * :—

A, the tie-beam, which is notched to receive the feet of the principal rafters; it is also notched on the wall-plate.

B, the king-post; the head is prepared to receive the upper ends of the principal rafters, and at the feet for the reception of the struts.

C, C, the principal rafters or principals; these are laid to the required pitch of the roof, the feet are joggled into the tie-beam, and the upper ends abut against the king, and are secured by straps and bolts.

D, D, the struts for supporting the principal rafters, &c.

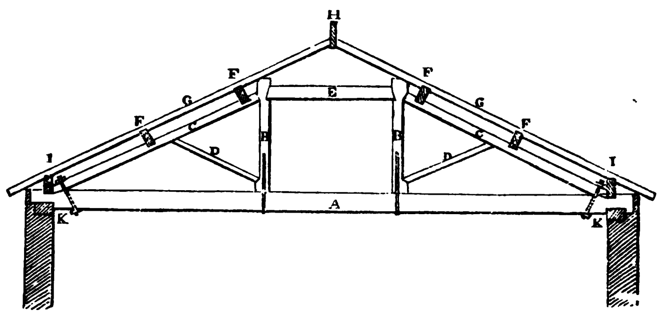
E, E, the purlines which are secured to the principal and to the common rafters.

F, F, the common rafters for receiving the outer covering.

G, the ridge-piece, against which the common rafters abut.

H, H, the pole-plates for receiving the feet of the common rafters, which are secured to the tie-beam.

Roofs of from 30 to 40 feet span may be supported with principals framed with two queen-posts, and one straining-beam between them, &c., thus, and of the following scantlings :—

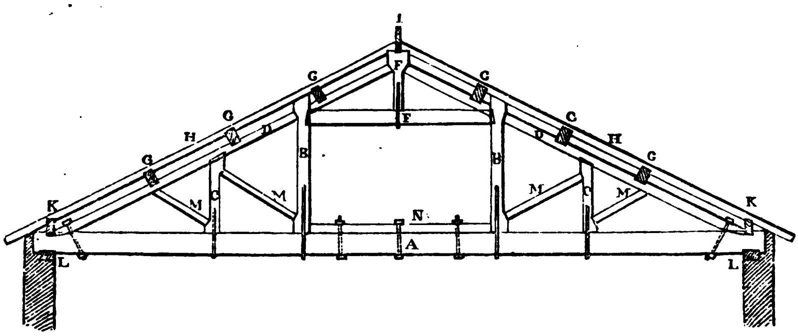


Span in feet.	Tie-beams.	Queen-posts.	Principals.	Straining-piece.	Struts.
	Ins. Ins.	Ins. Ins.	Ins. Ins.	Ins. Ins.	Ins. Ins.
35	11 × 4	4 × 4	5 × 4	7 × 4	4 × 2 *
40	12 × 5	5 × 5	5 × 5	7 × 5	5 × 2½

A, tie-beam.
B, B, queen-posts.
C, C, principal rafters.
D, D, struts.
E, straining-piece.
F, F, Purlines.
G, G, common rafters.
H, ridge-piece.
I, I, pole-plates.
K, K, Wall-plates.

Roofs of from 40 to 60 feet span may be framed with two queen-posts, and two straining-beams between them, and struts from the queen-posts to other smaller queens and struts.

The principals are much improved by trussing the upper straining-beam, as shown on cut. The scantlings being of the following dimensions :—



Span in feet.	Tie-beams.	Queen-posts.	Small Queens.	Principals.	Straining-piece	Struts.
	Ins. Ins.	Ins. Ins.	Ins. Ins.	Ins. Ins.	Ins. Ins.	Ins. Ins.
45	12 × 7	7 × 7	7 × 4	7 × 4	8 × 5	4½ × 3
50	13 × 8	8 × 8	8 × 4	8 × 6	9 × 6	5 × 3
55	14 × 9	9 × 8	9 × 4	8 × 7	10 × 6	5½ × 3
60	15 × 10	10 × 8	10 × 4	8 × 8	11 × 6	6 × 3

A, tie-beam.
B, B, large queens.
C, C, small queens.
D, D, principal rafters.
E, straining-piece, or collar.
F, king-post.
G, G, purlines.
H, H, common rafters.
I, ridge-piece.
K, K, pole-plate.
L, L, wall-plate.
M, M, M, M, struts.
N, Lower straining-piece.

The following Tables show the scantlings of purlines and common rafters, also according to Mr. Gwilt :—

PURLINES.

Bearing in feet.	Scantlings.
	Ins. Ins.
6	6 × 4
8	7 × 5
10	8 × 6
12	9 × 7

COMMON RAFTERS.

Bearings in feet.	Scantlings.
	Ins. Ins.
8	4 × 2½
10	5 × 2½
12	6 × 2½

The whole of the several joinings of the timbers must be well

tied together; the feet of the principal rafters are commonly joggled into the beam, and further secured by bolts or by straps, and they are fastened at their upper ends by being let into the heads of the posts, or by irons; and the tie-beam is supported by the posts, by means of stirrup-irons fixed at the extremity of the latter.

The height of the rise or pitch of a roof is generally between $\frac{1}{4}$th and $\frac{1}{8}$th of the span, the former being considered the ***true pitch*** for strength and security.

When the end of a roof is sloped off similar to the sides, it is said to be *hipped,* but if the ridge runs out straight with the face of the end walls or supports, such mode of termination is described as a ***gable-end.***

Struts are understood to be upright pieces of wood, and are employed to resist vertical compression; ***braces*** are diagonal pieces used to prevent any flexure in a framing, or to stiffen a truss; and those timbers exposed to the force of extension are termed ***ties;*** the term ***collar*** is applied to a tie extending from about the middle of a rafter to the corresponding one on the other side of a roof.

Rope-roll.—*See Drum.*

Rotary, Rotatory, or Concentric Engine (sometimes called a steam-wheel), an engine worked by the elastic force of the steam acting upon pistons fixed to an axis, whereby the latter is put into motion instead of being turned by means of pistons working in tubular cylinders, and communicated by the crank motion. The construction of an efficient engine after this system has been considered the grand desideratum with steam power, although some engineers assert, that it would not be able to exert more force than other engines with a similar quantity of steam. Notwithstanding various modifications may be made in steam-engines, to suit the purposes to which they are applied, yet it is very questionable whether much more will be accomplished than lessening the friction of the several parts by greater simplicity of construction. There have been two or three rotary engines spoken very highly of lately, as "Avery's Rotary Engine," and the "Pa-

tent Rotative Disc-Engine," also "Bunnett and Corpe's Concentric Engine."

RUBBLE-WORK, a rough description of masonry, the stones being merely axed on the face, and laid in as regular courses as suits the convenience of the mason, and well flushed with mortar, occasional bonders being inserted (which are more required in this description of walling than in any other), running through the whole thickness of the wall, to tie the whole together: chain-bond may also be used in rubble walls with great advantage, if many openings are required to be left. In good work the stones should be as large as the workmen can conveniently lift.

If the stones are laid in regular courses, the work is described as *regular coursed;* if otherwise, *irregular coursed* work: and when they are not laid in courses, but merely piled, or laid one upon another, according to the sizes of the several stones, it is termed *uncoursed* rubble walling.

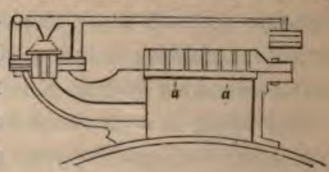
The filling-in work at the back of arches, and the like, is also called by this name, although not so properly speaking, as it consists of chippings and pieces of stones, of all shapes, thrown in without any attention to position.

SAFETY-VALVE, the valve usually employed in the boilers of steam-engines, to prevent explosions, which are constructed in such a manner that the power of the steam opens them when it is of a higher pressure than the boiler is calculated to bear, whereby the surplus power escapes, upon which the valve instantly closes again.

The conical or button-valve, is that most frequently employed, which is kept shut by a lever with a sliding weight.

The safety-valves of locomotive engines usually have a series of spiral elliptical springs instead of a weight, with an index to show the pressure of the steam upon the valve. It is sometimes found in practice, that valves of this description stick, and consequently offer a far greater resistance to the steam than intended, which has

led to the use of spherical valves; these supersede the necessity of any weight, and afford very little friction; they are, therefore, very suitable for the lock-up valves of an engine, as upon the top being screwed down, it is not very easy to tamper with them, and on account of their freedom from derangement (a lock-up valve is always attached to a boiler, in case the ordinary one should fail). The fusible valve is also used by some engineers, which consists of a safety-plate or plug, made of a certain mixture of metals, which becomes fusible before the steam attains a dangerous pressure. The safety-valves employed in France are required by government to partake of this principle; it is appended to the usual safety-valve. *a*, *a*, is the extra safety-plate, made of zinc, tin, and bismuth, being kept down by an iron grating. The only objection to this valve is, that it not only lets off the superabundant power, but the whole of the steam from the boiler with it, whereby the engine becomes stopped, although a safety-valve should be constructed of sufficient size to pass all the steam that the boiler can generate in an ordinary state of work. The steam *blown off* at the safety-valve often amounts to ¼th of the steam generated in the boiler.



SAND, a granular mineral substance insoluble in water. Pit-sand is superior to river-sand for all building purposes.

SAND-STONE, also termed Free-stone, a very serviceable and durable stone, when of good quality, being composed of grains of sand adhering together without any visible cement; it varies in its component parts, being at different places siliceous, argillaceous, and calcareous.

Sand-stone is generally found stratified, each strata varying in thickness from about that of a slate to many feet, as the enormous

blocks sometimes drawn from the Portland quarries: it is much used for building purposes, as it can be readily cut into any form.

SCAFFOLD, a temporary erection, formed of poles, for the purpose of building. In stone erections the poles are obliged to be used double, when it is termed a *double scaffold*.

SCANTLING, a term used in reference to timber, in the same sense as size, but with respect to breadth and thickness only; thus, a piece of timber 12 inches wide, and 6 inches thick, is said to have a *scantling* of $12'' \times 6''$.

SCARFING (of timber), the joining together of two wooden beams endways, which operation is resorted to when timber is required of longer lengths than can be procured in single pieces. The length of all scarfings should be at least twice the width of the face of the beam (although not always made so), well notched and wedged together. An iron plate, fixed beneath the scarfing, materially strengthens it, when the beams are not laying on a wall, or otherwise supported on the under side.

SCOOP-WHEEL, a certain description of wheel which is formed of cast-iron, and employed in conveying a stream of water upwards, from one pond, to another situated above it; they are therefore employed in a contrary manner to water-wheels, since, instead of being acted upon by the impulse of the water, they operate upon it, being turned by the aid of a steam-engine.

Scoop-wheels are much employed in the drainage of fenny land and levels. Mr. Joseph Glynn, C. E., who has had much experience in using them, usually makes the dip of the float-boards extend 5 feet below the water, where powerful engines are used; such a wheel being described as having a 10-feet head and dip, and the axis of the wheel should be 4 or 5 feet above the level of the river or outfall drain. Mr. Glynn states, that the best velocity for the wheel is 6 feet per second at the circumference, which gives it a centrifugal force quite sufficient to hold the water up against the breast of the stone trough or wheel-track, yet not enough to carry it beyond the point of delivery.

SCOURING-POWER.—*See Backwater.*

SEA-WALL, or REVETMENT, a retaining wall erected along the line of a coast adjoining the sea. —*See Harbour and Quay Wall.*

SECTION, a drawing of any object, representing it cut or divided into two parts.

Sections are either *vertical, horizontal*, or *oblique*, and generally represent plain surfaces.

A section of a line of country is a vertical section, made for the purpose of explaining the nature of the ground, as the soil within, and the level of the surface; and if intended for parliamentary purposes, it must be drawn according to the standing orders of the House of Commons, or 4 inches per mile for the horizontal scale, and 100 feet to an inch for the vertical scale.—*See Levelling.*

SECTIO PLANOGRAPHY, a method of laying down the section of engineering works upon the plan, and recently introduced by Mr. Macneill, and required, by the standing orders of the House of Commons, for all proposed railways, &c. It is performed by using the line of direction laid down on the plan as a datum-line; the cuttings being plotted on the upper part, and the embankments upon the lower part of the line; thus.

By this plan the nature of the undertaking may be readily understood, and the owners of property on the line will see how their land is crossed, whether in cutting or embankment, and the depth of same. If the former be coloured red, and the latter blue, it will further assist; or the cuttings may be represented by vertical lines ruled over them, and the embankment by horizontal ones. The regular section is required for the practical purposes of the engineer the same as usual.

Self-acting Inclined Plane (upon railways, canals, &c.), an inclined plane, worked by the gravity of the load conveyed; we first read of their being used in the year 1788, on which occasion a loaded boat was placed on a cradle and run down upon frame-work to the lower level, by the action of which some empty boats were also drawn up to the higher level. They are occasionally employed upon canals in America at the present time.

Inclined planes were formerly much employed upon colliery railways, having been applied soon after the introduction of iron rails and wheels, when they were adopted to counteract the increased velocity occasioned by them on the runs: the surplus gravity of the loaded waggons drawing up the empty ones, which at the same time served as a brake to them; each train of waggons was connected together by a rope, which is passed round a drum fixed at the top of the plane. Inclined planes are not applicable unless there is a preponderance of goods to be conveyed one way, sufficient to counterbalance the gravity of the empty carriages coming in the opposite direction.

Much advantage is derived from the adoption of self-acting inclined planes during the execution of railway works.—*See Inclined Planes and Double-acting Inclined Planes.*

Sewer, an arched covering, similar in shape to a tunnel, used for the conveyance of water.—*See Culvert and Drain.*

Sewerage. This term was formerly synonymous with drainage, but its signification at the present time is very different; drainage bearing more immediate reference to the recovering of marsh land, for the purposes of agriculture, whereas the former

implies the draining of a city or town of all superfluous water, and ridding it of all filth, whether accumulated by natural or by artificial causes; and this branch of internal convenience has not yet received that attention and consideration which it undoubtedly demands, it being very essential to the health of the people.

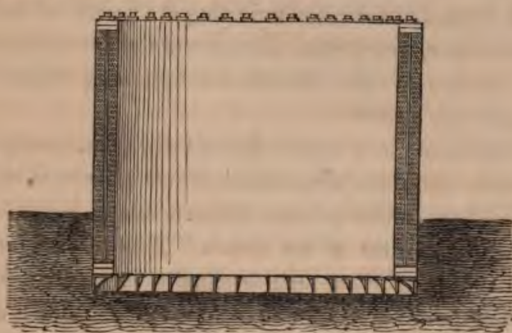
The drainage of open country is not a very difficult operation, where there are ample means provided to effect the undertaking, but the drainage of a large city or town is frequently a work of considerable difficulty, on account of the difference in the levels of the several streets, and the comparative lowness of some of them; hence all new shores required to be made in a city are obliged to bear reference to those already laid down.

SEXTANT, BOX SEXTANT, or POCKET SEXTANT, an instrument much used in surveying, for measuring horizontal angles only; it is sufficiently accurate for all general purposes, although a theodolite should always be used in laying out large triangles. A small telescope is sometimes attached to the sextant, to assist the sight, but it is not always used.

SHAFT, a vertical sinking or well, excavated and dry, for the purpose of working and ventilating mines, also tunnels, and for ascertaining the nature of the ground before commencing any engineering operations. The principal shaft of a mine is usually called the *engine-shaft*.

The brickwork of the shaft sunk for the working of the Thames Tunnel was first built up from the ground to the required height (40 feet), and then sunk to the proper level by loosening the ground from beneath it; proper precautions were, of course, taken to prevent any irregular settlement during the course of execution, by tying it well together; it was carried up upon piles, on which an iron curb was laid, wrought-iron rods, 2 inches diameter, were taken from thence to the intended height of the shaft, and secured into a top curb; the bricks were laid in cement, and further bound by timber hoops, half an inch thick. Upon the completion of the brickwork, the piles were removed from the bottom, and it was left standing upon the gravel; a thirty-horse

power high pressure-engine and raising gear were then fixed upon it, and after being kept a proper time to dry, the excavating was commenced from within it.



Section of the Working Shaft employed at the Thames Tunnel.

The shaft is 50 feet in diameter, 42 feet deep, and the brickwork is 3 feet in thickness. The two large ventilating shafts of the Kilsby Tunnel on the London and Birmingham Railway were also constructed by the same method; the ordinary shafts communicating with the tunnels on this railway are 9 feet in diameter, carried up in 9-inch brickwork, and supported below by a cast-iron curb, fixed in the crown of the tunnel.

SHAFT (in machinery), the term applied to a large axle. The shaft is one of the most essential parts for the conveying of motion in all machines; the action of the primary power causing it to revolve upon its axis, when any wheels fixed upon it are also carried round by it, as the shaft of a fly-wheel.

A small shaft is termed a *spindle;* shafts placed in a horizontal position are described as *lying*, and those situated vertically are called *upright*. The cylindrical form of shaft is considered superior to both square or feathered, but for large shafts hollow cylinders are best.

SHEAVE, FRICTION ROLLER, or PULLEY, a description of wheel much used in connection with inclined planes and fixed engines, being formed for the purpose of receiving the rope, whereby the friction of it is considerably reduced.

Fig. 2, is the working wheel, with its pit and tightening sheaves, and which is worked by a stationary engine.

The running sheaves used upon inclined planes are from 10 to 15 inches diameter, having their peripheries hollowed out to receive the rope, and are usually fixed about 8 or 10 yards apart, the axles resting upon a metal box or socket, which is well bedded in the ballasting, they are also sometimes fixed upon stone blocks. In cases where a plane is curved laterally, as parts of the Euston-square plane, the running sheaves are fixed in a slanting position, and at different degrees of inclination, according to their situation in the curve, a strong stay-bar being attached at the back of each, which enables them to support the pressure of the rope without altering their position. The proper angle for the same, is that which allows of neither an upward or a downward stress of the rope, but which presents the wheel in such a position that the strain shall be in a line at right angles with the axis; there is a double or endless rope to each set of rails, or each double line (there being four lines of rails laid down), each rope is 7 inches in circumference, and 4,000 yards long, and weighs 10 tons. Wooden friction rollers and frames are used on the Whitby and Pickering Railway.

The humming noise attendant on this method of working a railway, arising from the velocity with which the friction rollers revolve, is considered objectionable by some individuals, (more especially if occurring in crowded neighbourhoods); it has, however, been proposed to cover their edges with netting, as a preventive, although rather a doubtful remedy.

SHEET-PILING, a row of timbers driven firmly side by side into the earth. When the piling consists of planks, it is termed *pile-planking*, and which is sometimes joggled together. Sheet-piling is used for protecting foundation walls from the effects of water, also in the construction of coffer-dams, sluices, &c., and it is usually supported and secured to guide-piles and to waling-pieces situated along the top, by iron bolts.

Sheet-piling is always employed to support walls and other

works next rivers, canals, &c., and good clay should be well punned in at the back of the piles next the wall. Cast-iron sheet-piling has been recently adopted, and with considerable success.—*See Quay and Piles.*

SHIFT, a name employed in reference to the gangs of men employed in excavating upon railways, &c.; for instance, when two different sets of men are employed alternately, they are described as working *double shifts,* which is found more expensive than *single shifts,* although occasionally resorted to during the long days, where great speed is necessary. Night-work is also considerably more expensive than that performed in the usual working hours.

SHORE, or SHOAR, the name given to the pieces of timber placed diagonally against the sides of walls, or otherwise, as a prop or support to them; timber plates are usually placed at each end of shores, and the junctions are further tightened by wedges driven in between them.

SIDE CUTTING, a term applied to a cutting made along the side of a line of railway or canal, for the purpose of obtaining material for the embankment, when there is not sufficient excavation upon the line to form it.

SIDE-FORMING, a term applied to an embankment when made by a side cutting, and which constitutes the quickest way of forming an embankment, as the whole can be commenced at the same time from one side, and filled in at once towards the other, in which case the embankment is usually supported by steps cut at the bottom of it.—*See Road.*

SIDE SPACE (on railways), the distance on the outside of each line of rails, which is generally about 3 feet 6 on private, and 5 feet on public lines, as the London and Birmingham and Great Western Railways.

SIDELING GROUND, a line of country whose cross-section is inclined or sloping.—*See Earthwork, Side-forming, and Road.*

SIDING, PASSING PLACE, or TURN-OUT (on railways), a short length of additional trackway laid by the side of a line of rail-

way, and connected therewith at each extremity by suitable curves, the rails being constructed and disposed in such a manner that the carriages can either proceed along the main line, or turn into the siding, as may be required; to accomplish which, the portion of rails forming the junction of the siding with the main line is made moveable to suit either trackway, and is termed a *switch*, and the points where one railway crosses another are termed *crossing points*, which are generally fixed or immoveable; suitable grooves being left on the surface of them for the passage of the flanges of the carriage-wheels on either trackway.

The switches are mostly worked by an eccentric movement, which is enclosed in a cast-iron box, and it is effected on some railways by a vertical lever, which draws backwards and forwards, means being taken to secure it in the proper position.

The occurrence of sidings is most frequent in the vicinities of depôts and stations. Mr. R. Stephenson allowed one in every five miles in his estimate of the London and Birmingham Railway. —*See Switch and Crossing-point.*

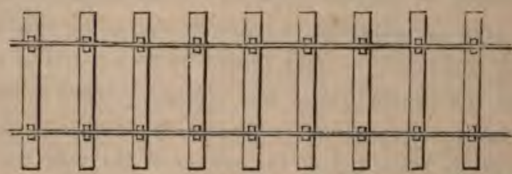
SILT, the alluvial soil washed down, and deposited upon the bottoms and sides of rivers by the action of the tides; the term is also indicative of any soft light description of soil.

SKEW-BACK, or ASKEW-BACK, the course of masonry forming the abutments to a segmental arch, or to the cast-iron ribs employed in bridges. It is necessary, in the latter case, to lay a plate of cast-iron upon the stone skew-backs, which is generally run through the entire width of the bridge, thereby forming a tie; but the iron ribs should not be fixed to this plate, particularly if they are of great span, on account of the alternate contraction and expansion of the metal, and a sufficient space should always be allowed for this variation.

The ribs of the Southwark Bridge, London, were originally secured by bolts to the masonry; but it was found necessary, during the execution of the work, to remove them in consequence of the injuries threatened.

SLACKED LIME.—*See Lime.*

SLEEPERS, the name applied generally to beams of wood laid horizontal in any works.



The sleepers used upon railways, upon which the railway chairs are fixed, are generally of oak, or larch timber, and about 5 by 9 inches scantling, 9 feet long, and 3 feet from centre to centre; the cost of the former may be stated at 7*s*. 6*d*. each, and the latter 6*s*. to 6*s*. 6*d*. A line of railway, formed of wooden sleepers, is much more elastic than one laid on stone blocks, and consequently easier for the passengers, and the process of kyanizing the wood sleepers, as generally practised, is expected to render them very durable.—*See Kyanize.*

SLEETCH, the thick mud laying at the bottom of rivers.

SLIP, or LAND-SLIP, a slipping of the earth of a cutting, or embankment, which most frequently occurs in the case of deep cuttings and high embankments; they generally arise from the want of stability of the soil, and general badness of foundation, also from the side-slopes being formed too steep; but clayey soil will slip at almost any slope, good drainage is, therefore, important in earth-work. During the formation of the Colne embankment, on the London and Birmingham Railway, the level frequently sank several feet in the course of a few hours, the base extending out to an enormous width, owing to the badness of the foundation. The only plan of procedure, in some cases, is by that of loading the slip itself with a sufficient quantity of earth, to enable it to bear the embankment above; slips are likewise caused by heavy rains: high embankments should always be exposed to the wet season of the year, and the succeeding winter, previous to the opening of the railway, as it tends much to consolidate and render them less liable to give way. Alternate beds of

clay, sand, or other soil, are very liable to slip, particularly if the clay should be easily acted upon by water, and if the strata dips, or inclines to the horizon; but it may be sometimes obviated, by driving piles into the faces of the side slopes, and laying binders across them, by which the earth is supported.

SLOPE, the name given to any inclination, but applied more particularly to those of excavations and embankments; the term *gradient* being adopted for the inclinations of the rails upon railways. The slopes of cuttings and embankments are usually measured by an instrument termed a clinometer, *(see Clinometer)* which indicates the angle of the slope; but their proportion of slope is usually expressed by comparing the horizontal dimension with the perpendicular, as an embankment, with a slope of 2 to 1, signifies a fall of 2 feet horizontally to 1 foot vertically.

The ratio of the slope to the perpendicular, is represented by the natural cotangent of the angle thus measured :—

TABLE OF SLOPES.

Angle.	Slope. To one Perpendicular.	Angle.	Slope. To one Perpendicular.
° ′		° ′	
75.58	¼	17.6	3¼
63.28	½	15.56	3½
53.8	¾	14.55	3¾
45.0	1	14.2	4
38.40	1¼	13.15	4¼
33.42	1½	12.32	4½
29.44	1¾	11.53	4¾
26.34	2	11.19	5
23.58	2¼	10.47	5¼
21.48	2½	10.18	5½
19.59	2¾	9.52	5¾
18.26	3	9.27	6

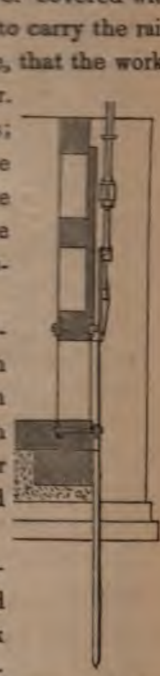
The proper slope for each description of soil can only be determined by observation, and the state of the slopes of any adjacent works forms a good criterion.

It is generally understood, that whatever angle the soil of a

cutting takes, without slipping, immediately after being teamed (the angle of repose), is sufficient for the embankment formed from it, but much depends upon the dryness of the soil at the time it is tipped into the embankment.

Oxford clay will stand with a slope in the proportion of 2 to 1, but London clay, whereof any height requires to be made, 3 to 1, although a less slope is sufficient for light works. Gravel or sand will stand at 1½, or 2 to 1; coal measures at 1½ to 1; chalk or chalk marl varies from ½ to 1, and good sandstone will stand at ¼ to 1; but much depends upon the height of the work, and other circumstances.

The vegetable soil upon the surface of the ground should always be carefully removed, and afterwards relaid upon the finished surface of the banks; and sown with grass seed, or covered with turf, for the purpose of strengthening them, also to carry the rain off; and this should be done as soon as possible, that the works may be protected from the effects of the weather. The banks are also sometimes planted with shrubs; and in situations where stone is plentiful, it may be advantageously employed in covering the side slopes, more especially the lower part or feet of the slopes.—*See Angle of Repose, Excavation, and Embankment.*

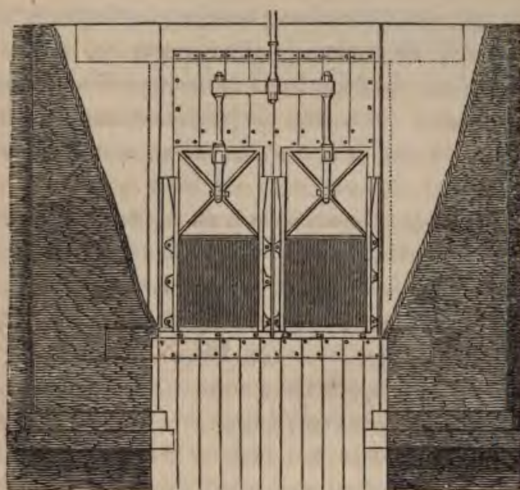


Transverse Section, showing Paddle opening.

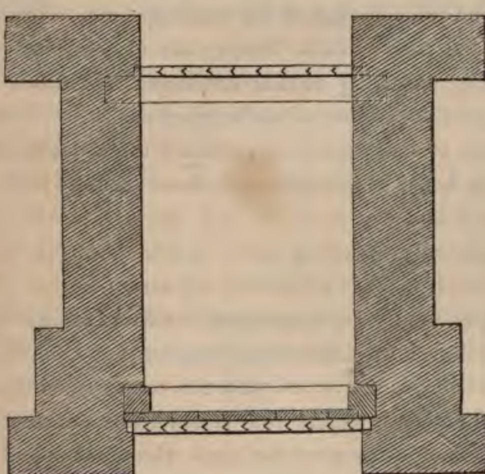
Sluice, or **Sluice-gate**, a description of sliding-valve, worked by a rack and pinion, and much used in connection with hydraulic works, which either retains the water, or allows it to pass through as may be required. It is set in a frame of timber or stone, by which the water is collected and raised for the purpose required.

The following cuts represent a sluice with a double valve, which, together with the slides, is formed of cast-iron, and the whole is supported by an oak frame and side walls, the foundation being protected by sheet-piling: both valves are opened by the

same movement, being connected together by means of wrought-iron rods, the upper one terminating with a rack, in which a pinion works :—



Elevation of Sluice taken on the outside face.



Plan of Sluice.

When a number of sluices are placed side by side, the erection is denominated a *weir*.—*See Lock-gate and Weir.*

SMELTING (of iron).—*See Iron.*

SOFITE, the underside of any overhanging erection, as the intrados of an arch, the underside of a cornice, &c.

SOUGH, a small drain, situated at the top of an embankment, for the purpose of conveying the surface water from it into the side drain. The term is also applied to an adit in some parts of the country.

SPANDREL WALL, the walls built on the back of an arch; the term, properly speaking, does not apply to any other than such as rest upon the extrados, and not to those situated upon the backing of the arch, although frequently applied to them.—*See Arch.*

SPHERICAL VALVE.—*See Safety-Valve.*

SPINDLE, the term applied to a small shaft, as to that of a pinion.

SPIRIT LEVEL.—*See Level (Spirit).*

SPOIL, or SPOIL BANK, the surplus excavation, which is laid by the side of a line of railway, canal, or other work, to save the expense of removal, and which occurs when the amount of cutting upon the line exceeds that of the embankments.—*See Earthwork.*

STAITH, the line of rails forming the extremity of a railway, and generally occurring next rivers, being laid down upon high platforms, for the purpose of discharging coals, &c., into the holds of the vessels or receptacles prepared for them. The staiths project over the banks of the river, and shoots usually lead from them to the vessels below.

STARLING.—*See Cutwater.*

STATIONARY, or FIXED ENGINE, any steam-engine of a fixed or permanent nature; but one connected with a railway is more immediately alluded to. Stationary engines are usually employed upon inclined planes, to convey the carriages along, and are constructed on the low-pressure system; they are also sometimes used upon the other parts of the line. Recourse is had to a fixed steam-engine where an incline is too great to be overcome by the gravity of the meeting trains, owing to the traffic being equal in

each direction; and where it is necessary to pass a steep hill, inclined planes are sometimes made on each side up to the summit, upon which an engine is fixed. In all such cases of inclined planes worked by fixed engines, their inclination should be sufficient to enable the empty waggons to descend by gravity alone, pulling the rope after them, which would thus be in readiness to return with the train passing up.

The principal objections to the adoption of fixed engines is, the great friction arising from the rope, also the inconvenience of same where passenger trains are conveyed along the line; but they are not so objectionable when situated at the termination of a railway.

There is not much difference in the expense between the adoption of fixed and of locomotive engines—for instance, the Durham and Sunderland Railway is entirely worked by fixed engines, upon which the charge for conveying coals is precisely similar to that upon the Stanhope and Tyne line, where locomotives are used, viz. 1.13*d.* per ton per mile, but the charges for the same upon the Seaham and Clarence Railway, which is worked by locomotives, is only 0.75*d.* per ton per mile.—*See Friction, Inclined Planes, and Stationary System.*

STATIONARY PLANE, a plane worked by a stationary engine and rope, as the Euston-square Plane, at Camden Town, on the London and Birmingham Railway.

STATIONARY SYSTEM, a method of facilitating the conveyance of carriages along railways, &c., by the action of two or more fixed steam-engines, according to the inclination and length of the road.

Some of the private railways in the north are worked by stationary-engines throughout, which are fixed at certain distances, in regular succession, reciprocating with each other. This plan was partially recommended by Mr. J. Walker and Mr. J. U. Rastrick, Civil Engineers, in their celebrated Report to the Directors of the Liverpool and Manchester Railway, in 1829, on the subject of the best motive power to be employed on that line;

but locomotive engines at that period may be described as being in their infancy.

The destruction of ropes by the *stationary system* is very great, which is mainly attributable to the sudden straining to which they are subjected at the time of the train's starting; the bottom of a plane should therefore be level, or even slightly inclined in the opposite direction, to assist the start; which plan is successfully practised on the Brussleton Plane, on the Stockton and Darlington Railway.—*See Stationary or Fixed Engine, and Reciprocating System.*

STEAM, the vapour arising from any liquid when heated to the boiling point, which possesses very great force or power. It is generally allowed, that of all known fluids water is the best adapted for producing steam. The fluid is composed of a vast quantity of separate bodies, or atoms, having a great natural attraction for each other, and cold has the effect of increasing this attraction: heat, on the contrary, decreases it; in other words, heat possesses the power of separating these atoms, and repulsive force is imparted to them, equal to the degree of heat.

The following Table, by Dr. Dalton, will be found very useful:—

TABLE of the Expansive force of Steam when contained in a closed vessel, taken at every 10° of Temperature from 212° Fahrenheit (the boiling point) up to 320°.

Temp. Fahr.	Pressure of Steam, or the force which it will exert to enter into a vacuous space.			Pressure of the Steam against the atmosphere, when the barometer is at 30 inches, or the force it will exert to escape from the closed vessel into the open air.		
	Column of Mercury.	Column of Water.	Pressure, per square inch.	Column of Mercury.	Column of Water.	Pressure, per square inch.
	Inches.	*Ft. In.*	*Lbs. Oz.*	*Inches.*	*Ft. In.*	*Lbs. Oz.*
212	30.	33 11	14 11	The Steam	equal to the	atmosph.
220	35.	39 6	17 1	5.	5 7	2 7
230	41.75	47 2	20 7	11.75	13 4	5 13
240	49.67	56 1	24 4	19.67	22 3	9 10
250	58.21	65 9	28 8	28.21	31 11	13 14
260	67.73	76 6	33 2	37.73	42 8	18 8
270	77.85	87 11	38 1	47.85	54 1	23 7
280	88.75	100 3	43 7	58.75	66 5	28 13
290	100.12	113 1	49 0	70.12	79 3	34 6
300	111.81	126 4	54 12	81.81	92 6	40 2
310	123.53	139 6	60 8	93.53	105 8	45 14
320	135.	152 6	66 1	105.	116 5	51 7

Steam is produced upon the water being heated to 212° Fahrenheit's thermometer, or the boiling point. It is perfectly colourless when pure, or unmixed with other ærial matter, but is white and cloudy when mixed with air, as it thereby becomes partly condensed, or reduced to a temperature below the boiling point, when it again becomes water.

STEAM-BOAT, or STEAM-VESSEL, a vessel propelled by the force of steam.

Perhaps of all the innumerable advantages derived from the application of steam, its utility for the purposes of navigation is the most beneficial and important to mankind. The idea of propelling vessels by steam was, in all probability, coeval with the introduction of that power; as, on referring to the period of its application, or about the year 1700, we find many individuals famous for their ingenuity in mechanics endeavouring to adopt it for the purpose of propelling boats; among whom was the celebrated Savery, who was the first to introduce the steam-engine in a practicable shape, and his contemporary Dr. Papin, the inventor of the safety-valve; also Mr. Hulls, the inventor of the crank motion (in the year 1737), so essential to the rotary motion of the paddles.

There have been many ways tried of employing steam for the propulsion of boats on water: in the usual mode adopted, it is made to turn a shaft situated athwart the vessel, by means of cranks, and large cast-iron wheels are fixed at each end, having paddle-boards fastened round them, like under-shot water-wheels; these paddles, or floats, strike the water somewhat similar to common oars, and they are placed in such a depth of water that each paddle is just immersed when in a vertical position, or as it passes the centre at the bottom of the wheel. An experiment of propelling vessels by means of an archimedian screw has lately been made, which was fixed at the stern; and it is imagined, from the uniformity of its action, and the total absence of all swell in the water, that this plan would be very advantageous: although the principle is not new.

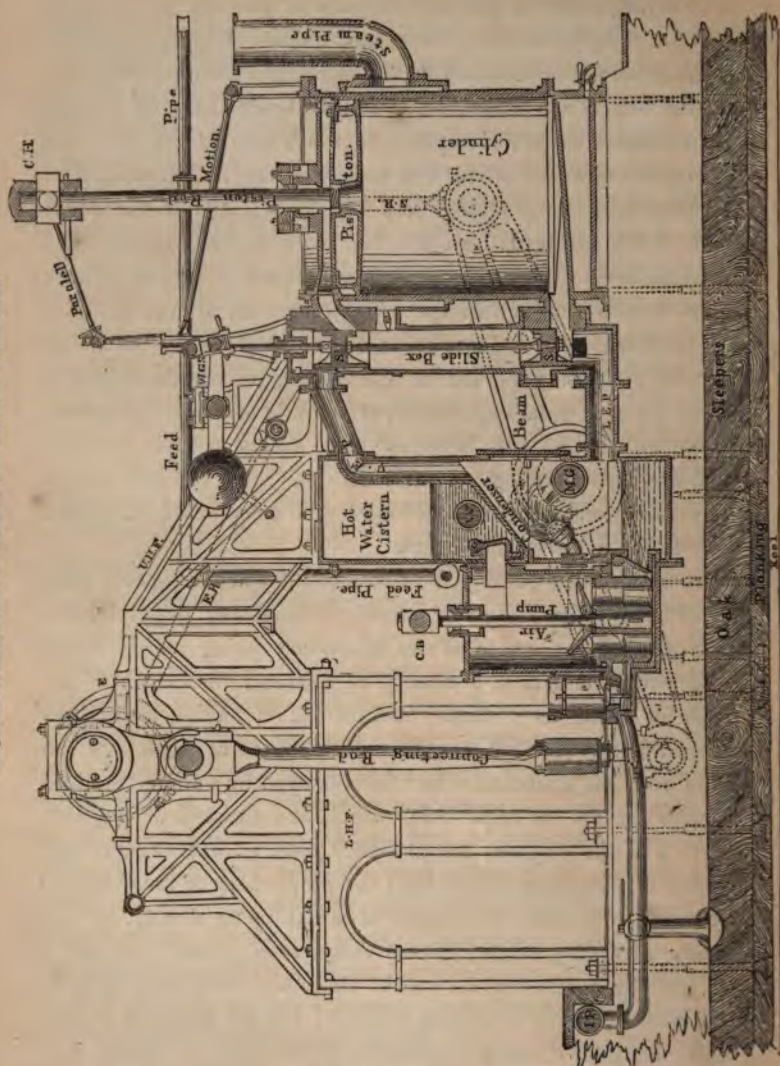
One of the first instances, if not the first of a vessel being absolutely propelled by the power of steam, was that by the Marquis de Jouffrey, which took place upon the Saône, at Lyons, in the year 1782; the next was constructed under the direction of a Mr. Miller, in the year 1789, and succeeded very satisfactorily, on the Forth and Clyde Canal: after which, several experiments were made; and that of the celebrated American engineer, Mr. Robert Fulton, was among the most successful, the engines having been supplied and fitted by Messrs. Boulton and Watt. The vessel was named the "Vermont," which was the first steam-vessel run as a regular packet-boat, having been launched at New York, in the year 1807, and plied between that city and Albany, a distance of about 150 miles, performing the voyage in 32 hours, which gives a speed of nearly 5 miles an hour (about ⅓rd the speed now attained): the length of the boat was 133 feet, depth 7 feet, breadth 18 feet; the boiler was 20 feet long, 7 feet deep, and 8 feet broad, and with only one steam cylinder, which was 2 feet diameter, and 4 feet stroke of piston; the paddle-wheels were 15 feet diameter, (dipping 2 feet into the water) and 4 feet broad; and the burden was 160 tons.

It was not until 1812 that a steam-packet experiment was again attempted in this country, which occurred on the Clyde; another was tried at Bristol; and these were shortly after followed by many others: at length they became pretty general—although the engines were of very imperfect construction, one steam cylinder only being employed; whereas two are now invariably used, each working a crank, fixed upon the axle of the paddle-wheels, and situated at right angles to each other, so that when one is passing the dead points, the other is exerting its greatest power.

Steam-packets commenced making regular sea voyages in the year 1818, and they have continued extending their bounds ever since, voyages of considerable length being now made; among which may be cited those of the Great Western, and other steam-packets to America: and voyages yet more extensive are talked of.

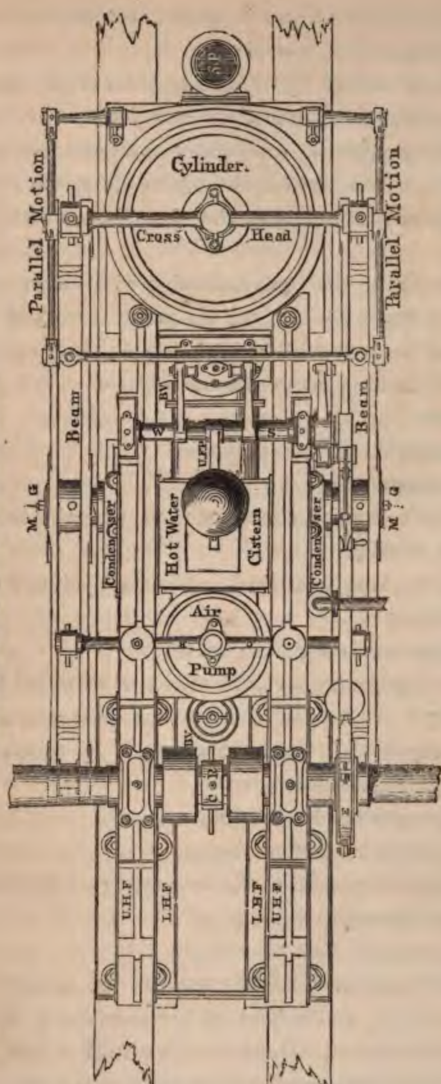
The arrangement of the several parts of the marine engine is somewhat different to the general land engine, it being important to reduce the space occupied by the machinery as much as possible; the boilers are consequently of less dimensions, but a much more extensive surface is exposed to the action of the fire: the employment of a pair of engines, instead of one, is independent of the advantages before stated, very beneficial; thus in the event of one being disabled the other can work the vessel, which has sometimes been the case; and the employment of several distinct boilers is also very advantageous, although not always adopted, as in the event of a concussion it is not likely that all would be ruptured. A ready method of disengaging the paddle-wheels is another point of great importance, as it would enable a steam-boat to cope with sailing vessels by the same means, both as respects speed and manœuvreing. It may also be remarked that proper safety-valves and gauges should always be constructed, to ensure safety to the passengers and crew.

The steam-boats employed in this country at the present time are principally upon the low pressure condensing principle, *(see Steam-Engine)* the whole of the machinery being placed below deck, which renders it necessary to diminish the height of the engine as much as possible; and instead of having a working-beam over the cylinders, a cross head is placed at the top of the piston rod, the action of which is conveyed by parallel motions to cross beams on each side, which are situated at the bottom part of the engine; the motion, compared with regular land engines, is consequently inverted; the proportions of the cylinders also differ from them, the length of stroke being shorter, for the purpose of saving height, but the diameter is greater: the valves and gearing connected therewith, air-pump, condenser, &c., do not differ essentially from land engines; but the governor is altogether omitted, it being impracticable to work an engine with great regularity, in consequence of the agitation of the water, and other contingencies.



Longitudinal Section of one of the Engines of the "Red Rover" Steam-packet.

S. P., the steam-pipe which conveys the steam from the boiler to the slide box.



Plan of one of the Engines of the "Red Rover" Steam-packet.

U, E, P, upper eduction pipe.
L, E, P, lower eduction pipe.

These pipes are employed to pass the steam to the condenser, at the termination of each stroke.

S, S, slides or valves, by which the steam is admitted alternately to the top and to the bottom of the cylinder.

M, G, main gudgeons, upon which the beams are placed.

C, H, cross heads, fixed at the top of the piston rod.

S, R, side rods connecting the cross heads with the working beams.

C, R, connecting rod communicating with the crank.

C, B, air-pump cross-bar, the air-pump is worked by two slide rods from the beams, and the hot water and bilge pumps are also worked from the air-pump cross-bar.

E, eccentric.

E, R, eccentric rod.

E, A, eccentric arm.

These constitute the eccentric motion, whereby the slide-valves or slides are worked.

W, G, S, working gear shaft, which is operated upon by the eccentric motion.

B, V, upper and lower blow valves.

Upon starting the engines, the steam is admitted into the condenser through the upper one; it then passes out through the lower, blowing out all the air and water, by which a partial vacuum is obtained in the condenser.

U, H, F, upper head stock frame.

L, H, F, lower head stock frame.

The engine and paddle-shafts are supported by these frames.

W, waste water stop valve pipe.

P, injection pipe.

In American steam-boats the engines are mostly on the high pressure principle, and a part of the machinery is placed upon deck, whereby the whole extent of the hull is left open for cabins, which are, consequently, extremely capacious; their vessels not being much employed for sea navigation, nor subjected to winds and waves, as in our country, can be safely built more

slender and of a more delicate form, which increases their speed much; their bows also glide over the water instead of cutting through it, and they are further assisted by the engines being made much more powerful than ours; and the length of stroke is very great, although one engine only is employed, a counterbalance being generally attached to the paddle-wheels, in some cases, to enable the engine to get over the centres; their great length of stroke, however, allows time for a degree of momentum, which is mostly found sufficient; the paddle-wheels also assist on account of their large diameter, acting like fly-wheels: where two engines are employed their connecting rods are not attached to the same axle, but each drive a wheel independent of one another.

The deposit occuring in the boilers of steam-boats is much greater than those of other engines, owing to the salt and other impurities contained in the water employed; and this incrustation becomes considerable, if not frequently attended to it sometimes acquires a thickness of upwards of an inch, and is so hard that it can with difficulty be removed; a considerable portion of the heat is consequently abstracted by it, and the wear of the metal increased, besides rendering it more liable to accidents. The means of preventing incrustation were very inadequate previous to the introduction of Mr. Samuel Hall's patent condenser, in which the condensation is effected without the introduction of a jet of cold water (as in Mr. Watt's engines), but by contact, or the effect of cold water chambers only; the water employed is also distilled, and made available over and over again, allowance being made for leakage, &c.: there are also several other advantages connected with the invention, as the freedom of the condenser from the pressure of any air, which renders the vacuum more perfect.

The engines of steam-boats are usually considered to consume about 8lb. of coal per hour, per horse power.

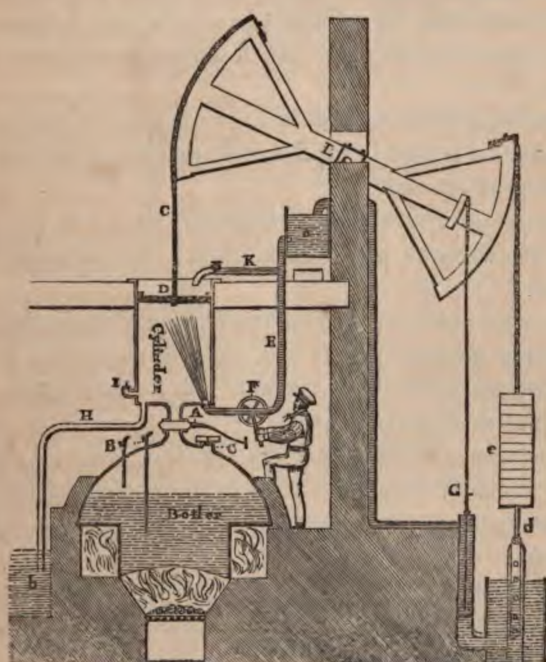
Steam-Engine, an engine worked by the power obtained from the expansion and contraction of the steam from boiling water, which is adopted for the first moving power to the many various machines employed at the present time, as for the raising of water

for impelling machinery for mining, manufacturing, and agricultural purposes, also for navigation and for land carriage.

Every modification of the steam-engine derives its power from either one of the following causes, or from a combination of both, viz., from the property of water to expand in bulk under the action of heat, assuming the appearance of vapour; and from the sudden return of this expanded water or vapour to its original size, upon the introduction of cold, thus steam is generated upon the water being heated to the boiling point (212° of Fahrenheit's thermometer); and if it be contained in a close vessel, and subjected to the action of increased heat, it becomes yet more rarified, exerting an increased pressure on the sides of the vessel, and this pressure is regulated by the degree of heat applied; it may be increased until the power of the steam bursts the vessel—a positive power is thus obtained, which constitutes the *first power* before stated. If instead of an inclosed vessel a short tube be employed for the reception of the steam, having a sliding top working within it, the power of the steam will force the lid upwards, instead of bursting the tube, and upon a quantity of steam having forced its way upwards, by removing the fire, and applying cold water upon the outside of the tube, such steam will almost immediately be condensed or reduced again to water, occupying only $\frac{1}{1700}$dth part of its former size, or thereabouts, (as a cubic foot of steam, when its elasticity is equal to 30 inches of mercury, only occupies a cubic inch of water when condensed), a void or space unoccupied either by air, water, or steam, will consequently be left at the upper part of the tube, and the pressure of the atmosphere upon the outside of the tube, which is equal to a force of nearly 15 lbs. to the square inch, will immediately force down the sliding top to the surface of the water condensed from the steam: here, then, another direct force is obtained, and which forms the *second description of power* before stated; the system of action just described constituting the principle of the common atmospheric engine, the condensation being effected within the cylinder.

It is very probable that some of the properties of steam were known to the ancients, but it was not until about the early part of the seventeenth century that its power was made available for the working of machines. A mining engineer, named Savery, appears to have been the first who constructed and publicly exhibited an engine, acting by the expansive force and subsequent condensation of steam, and which he applied to the raising of water in the year 1699; Dr. Papin next introduced the safety-valve to an engine of his own contrivance in 1707. The steam-engine also received various modifications and improvements from Mr. Newcomen, in the year 1707, (whose engines are known by the name of *atmospheric engines*); and successively by Messrs. Beighton and Smeaton, who may be said to have perfected this class of engines.

The accompanying cut represents an atmospheric steam-engine upon Mr. Newcomen's principle:—



A, the regulator, or regulating valve, whereby the communication between the cylinder and the boiler is opened and closed when required.

B, the gauge-cocks for ascertaining the height of the water in the boiler, which are so arranged that the extremity of the one is a little below the level of the water, and the other a little above it, therefore, upon their being turned, one should discharge water, and the other steam, provided the water is at its proper level.

C, the safety-valve.

D, the piston working in the cylinder, which is open at the top.

E, the injection-pipe for conveying water from the cistern, *a*, into the cylinder, to condense the steam.

F, the injection-cock.

G, the pump for supplying the cistern, *a*, with water from the well.

H, the eduction-pipe for conveying the condensed steam and injection water from the cylinder to a cistern placed below it, *b*, a valve is placed in its lower end to prevent the water rising up the pipe.

I, the snifting or blowing-off valve, for passing off any air from the cylinder; it is used to expel the air from the cylinder at starting, and opens outwards.

K, a pipe used to discharge water on the top of the piston, whereby the whole is preserved air-tight; it is furnished with a stop-cock.

L, the beam which turns on an axis fixed in the wall, the piston, rod, *c*, being attached at one end, and the pump-rod, *d*, at the other; a weight, *e*, is fixed on the latter rod, for the purpose of aiding the descent of the pump-rod.

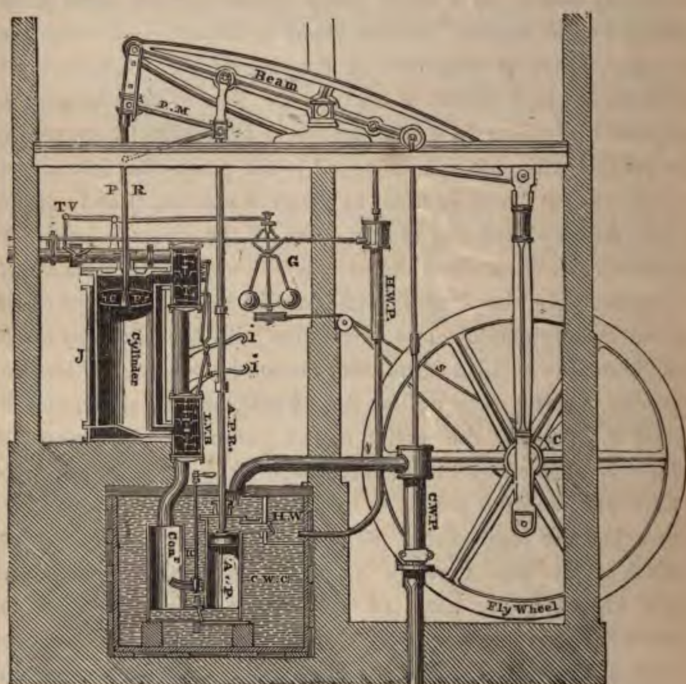
It is necessary to state, that the regulating valve, A, and the injection-cock, F, were not worked by the engine, as the valves of steam-engines at the present time, but were attended to by the engine man.

These steam-engines continued in general use until the time of Mr. Watt (about the year 1770), who effected great improvements

in them; his first engine is known by the name of the *single acting engine,* being applied to the same purposes as former engines, viz., the drawing up of water from mines, and like purposes; and its summary action was not unlike them. He inclosed the cylinder in a case or jacket, and filled the space inclosed between them also with steam, by which the cylinder was kept constantly at the same degree of temperature, but his prime improvement was the introduction of a condenser, which consists of a vessel exhausted of air and other fluids, and connected with the cylinder by a pipe, through which the whole of the steam from the cylinder escapes, being sucked into it, where it is very speedily condensed: the condenser is placed in a cistern of cold water, which is kept constantly flowing by a small pump, termed the *cold water-pump,* worked by the engine; another pump is also attached, called the *air-pump,* which is employed in drawing off the contents of the condenser at each stroke of the piston. Mr. Watt subsequently adapted his engine to drive machinery generally, by converting the reciprocating motion conveyed to the pump-rods into a rotative movement; and, in order to preserve a constant and uniform power, he employed the elastic force of the steam to impel the piston up as well as down the cylinder—hence the term *double acting engine.* He also invented the *parallel motion,* in place of the chains usually employed in connection with the beam, by which the piston was enabled to transmit motion by pushing or thrusting upwards, as well as by pulling downwards, as heretofore; and the *fly-wheel,* to render the motion of the piston regular throughout, which is effected by the momentum of its weight, carrying the axle round the dead points, or those parts where the power of the crank has the least effect: the crank having been previously patented by Mr. Washborough, he constructed another movement, since known by the name of the *sun and planet wheels,* but the former is generally employed at the present time; and he introduced a contrivance, called the *governor,* to regulate the supply of steam from the boiler to the cylinder, and insure the uniform velocity of the piston. He also introduced the improved way of

working the piston by the elastic force of the steam, which is said to have partly arisen from his having found some inconvenience from the accelerated motion acquired by the piston towards the end of the stroke, when it occurred to him to cut off the steam before the piston arrived there, and which he afterwards practised with great advantage, thus, by cutting it off at $\frac{1}{3}$rd; the rest of the descent was accomplished by the elastic force of the steam alone, and a proportionate saving consequently accrued. To these modifications of the steam-engine the term *low pressure*, or *condensing engines*, is now applied.

The accompanying cut represents Mr. Watt's double acting steam-engine :—



The cylinder is enclosed in a jacket, *j*, and C, P, is the piston.

P, R, the piston-rod.

S, P, the steam-pipe.

U, V, B, upper valve box.

L, V, B, lower valve-box.

The valves are employed to admit the steam to the cylinder, and to draw it off at the termination of each stroke, each box being furnished with a steam-valve and an exhausting valve, and they are put into proper action by levers, *l*, *l*, connected with them by jointed rods; and the levers are worked by pins placed on the piston-rod of the air-pump. The valves of steam-engines are generally worked at the present time by means of an eccentric placed on the axle of the fly-wheel.

G, the governor, which is mostly put into motion by a strap or rope from the main shaft.

Con^{r}, the condenser.

I, C, the injection cock.

A, P, the air-pump.

A, P, R, the air-pump rod.

H, W, the hot well.

C, W, C, cold water cistern.

H, W, P, the force-pump by which the water is conveyed from the hot well to the supply of the boiler.

C, W, P, pump to furnish cold water to the condensing cistern.

C, the crank.

P, M, the parallel motion.

The difference between a high pressure engine and a low pressure lies in the former being worked by the expansive force of the steam acting upon the piston, despite of the pressure of the atmosphere at the back of same (about 15lbs. per square inch, as before stated); it is consequently required to be of very great pressure, whereas a low pressure is worked by the force of the steam upon the piston, but a vacuum is formed upon the other side by means of the condenser, whereby steam of little pressure

may be used; a force of 1 or 2 lbs. beyond that of the atmosphere is all that is required.

Leupold gave the first plan for a high pressure engine; Mr. Watt also vaguely proposed one; but Messrs. Trevithick and Vivian were the first who constructed a high pressure engine, which they effected in the year 1802, and adopted, amongst other purposes, as a locomotive, for which it suited admirably, enabling them to dispense with the condenser, and the whole of the machinery connected therewith.—*See Locomotive Engine.*

When steam-engines were first introduced, they were used generally for many mechanical purposes where horses had been previously employed, hence the origin of comparing the power of engines with that of horses. The resistance which an engine is capable of overcoming is called the *power* of the engine, and that which is ascribed to it by its makers, is termed *the nominal power*, which of course varies according to the velocity of its action; most engines work considerably above their nominal power, as that is understood to refer to their power with steam of the ordinary pressure only. Mr. Watt's standard was an effective pressure of steam in the cylinder of 6 lbs. per circular inch for each horse power of the engine, and a speed of 220 feet per minute. The total power exerted by the steam in the cylinder is called the *gross power*, which includes that employed in overcoming the friction and resistance of the engine; and the *effective power* is that portion of the power absolutely delivered at the crank-shaft, the remaining portion of the gross power being employed in overcoming the friction of the engine; comprising not only that of the piston, pump, buckets, stuffing-box, and bearing parts of the engine, but the resistance due to the water lifted by the engine-pumps, which of course varies according to circumstances. Mr. R. Armstrong states the amount of this last resistance at 2 lbs. per circular inch on the area of the piston in the best modern engines, but the ratio is much less in large engines than in small ones. The term *duty* is used in Cornwall to express the load which an engine is capable of raising a given perpendicular height, by the combustion of a

given quantity of fuel, which is partly regulated by the construction of the furnace, boiler, &c.

It is held by some engineers, that a steam-engine should possess an area of piston equal to 27 circular inches per horse power, and that a boiler should have 27 cubic feet for the same, half of the latter being reserved for steam, and the other occupied by water. It was shown by Mr. Watt, that the evaporation of a cubic foot of water was the proper measure of 1-horse power, the boiler is therefore, *cæteris paribus*, the real depository of its power; the best length for a cylinder, is twice its diameter, some make it $2\frac{1}{2}$: in marine engines it is much less, or about the same as its diameter: whatever be the form of the cylinders of two engines of equal power, the quantity of steam passed through them per minute is precisely the same, unless the pressure of the steam differs in each, when that possessing steam of the highest pressure will have the smallest cylinder. The greater the diameter of the piston, compared to its length of stroke, the less will be the velocity of its action. The area of steam-ports allowed by Mr. Watt for stationary engines was equal to $\frac{1}{25}$th part of the area of the cylinders, which admits sufficient steam to move the piston at a rate of 220 feet per minute, which he states as the best velocity for it; the diameter of the steam-pipe is usually about $\frac{1}{5}$th that of the cylinder; some allow it 1 square inch of section per horse power.

Mr. Tredgold gives the following rule for finding the effective power of a steam-engine:—

Multiply the square of the cylinder's diameter in inches by the mean effective pressure on the piston in lbs. per square inch, and by the velocity of the piston in feet (which is obtained by multiplying double the length of stroke by the number of strokes per minute), point off three figures, and divide the product by 42, and the quotient will express the number of horses' power; thus, suppose the diameter of the cylinder to be 36 inches, length of stroke 4 feet, and number per minute 24, and the mean effective pressure on the piston 4 lbs. per square inch, then—

No. of strokes per minute	24	Diameter	36 inches
Length of stroke . . .	8		36
Velocity of piston . . .	192		216
			108
			1,296
		Mean pressure	4 lb.
			5,184
		Velocity of piston	192
			10368
			46656
			5184
		42)	995328 (23.7 horses' power.
			84
			155
			126
			293
			294

Number of horses' power 23.7.

In reference to the mean effective pressure on the piston, it may be stated, that not one-half the water evaporated from the boiler is absolutely expended in working the piston, the remaining portion being lost in passing from the boiler to the cylinders, in working the air-pump, and by friction, also on account of leakage, and various other contingencies. Mr. Tredgold calculated $\frac{632}{1000}$ of the power of an engine to be thus lost—now supposing the force of the steam in the boiler be equal to 35 inches of mercury, or 5 inches above the pressure of the atmosphere, and the temperature of the uncondensed steam 120°, and its force 3.7 inches, then $\left(\frac{35 \times 632}{1000}\right) - 3.7 = 18.42$ or 9.05 per square inch for the mean effective pressure on the piston.

In the case of high pressure engines, the whole pressure of the atmosphere must of course be deducted from the force exerted by the steam in the boiler, in order to ascertain the real effect of the engine, and if the engine works expansively, allowance must also be made for it.—*See Air-Pump, Fly-Wheel, Governor, Parallel Motion, Piston, Steam, Safety-Valve, &c.*

STEAM-GAUGE, a contrivance connected with the boilers of steam-engines, and employed to indicate the pressure of the steam, thereby forming a guide, whereby the fire is regulated. The steam-gauge usually consists of an inverted syphon, or bent tube, formed of wrought-iron, and secured at one end of the boiler, and a sufficient quantity of mercury is placed in it to counteract the pressure of the steam, the other end being open to the atmosphere; the level of the mercury, therefore, varies with the pressure of the steam, the amount of which is communicated to an index on the outside; it may also be said to constitute an extra safety-valve, for if any thing should prevent the ordinary safety-valve from acting, the whole of the mercury must be driven out of the tube.—*See Boiler.*

STEAM-PIPE, the pipe communicating with the upper part of the boiler, through which the steam passes in its passage to the cylinders.—*See Steam-Engine.*

STEAM-WHEEL.—*See Rotary Engine.*

STEAM-WHISTLE, a device attached to locomotives, for giving warning to the passengers and others when the engine is starting. It consists of a pipe situated at the top of the boiler, with a cock to same, within reach of the engine man; who is thus enabled to turn the steam on or off at pleasure. When turned on, it issues through the pipe into a hollow cup, passing through four holes in a plate placed at the bottom of it; the steam then escapes at the top, round the thin edge of the cup, striking the same with considerable force, which produces a loud shrill whistle, and can be heard at a distance of many miles.

STEPS, or BEARINGS, those parts which receive the lower gudgeons of upright shafts.

STONE, or ROCK, an aggregation of several hard mineral substances, insoluble in water.

Notwithstanding the general diversity of nature, the same rocks are common to all quarters of the globe; the crust or covering of the earth being composed of a number of layers, termed *strata*, of very different appearance compared with each other, yet com-

posed of comparatively few primary elements, but they are so concreted or mixed together, and are in such a number of proportions, as to produce considerable variety; and most of the rocks lying in beds contain foreign matter, as shells, fragments of other rocks, and of animals, fishes, trees, and plants.

Stones are named either according to their chemical constituents, physical properties, or from their external appearance, or the names of the places from whence quarried. Stone for engineering purposes should possess *strength*, or the power of resistance, in every direction; also *hardness*, or the power of attrition, which enables it to resist blows; and *durability*, that it shall not be affected by any natural agents, as the atmosphere, water, heat, and frost. Stone is classified generally under three heads, although the component parts of some stone partakes of each class, viz., 1st, the *silicious*, which is least liable to decay, comprising granite, sandstone, &c.; 2ndly, the *argillaceous*, which comprehends basalt, and nearly all the slate-stones; stone of this class, though excessively hard when laying in their beds, are not suitable for building purposes, as upon their being quarried and removed, they are soon affected by the atmosphere; and 3rdly, the *calcareous*, which is a very plentiful and valuable class, comprising all limestones, from marble downwards; it is the principal ingredient in all cements; and the most celebrated statues of antiquity being formed of calcareous stones, bear proof of its great hardness and durability.

The under beds of stone, in most quarries, are harder and thicker than the upper ones, it therefore frequently happens that the best stones are neglected, or very rarely worked, on account of the expense of blasting and removing those beds covering them, particularly where time and first cost are regarded; and it is generally considered that stone employed in the vicinity of its native quarry withstands the effects of the atmosphere better than when used further off—say a distance of 40 or 50 miles, or upwards.—*See Bath-stone, Portland-stone, Lime-stone, Sand-stone, Granite, Natural or Quarry-beds, and Quarry.*

STONE BLOCKS, on railways.—*See Blocks (Stone).*

STOP-PLANKS, a certain description of dam employed on canals.

It is necessary to provide weirs on the line of a canal, at certain distances from each other, except in cases where the space between the locks is very short, to prevent the loss of water that might arise from an accident, and for other purposes.

This is usually done by contracting the water-way at such points, and carrying up wing-walls from below the bottom of the canal, and vertical grooves are made in the face of the masonry upon each side, corresponding with each other, for the insertion of the hatches, or *stop-planks,* as they are called. Provision is made for stop-planks in most hydraulic works—for instance, grooves are made at each end of a lock, on the outside of the chamber, in order that the water may be kept out during any repairs.

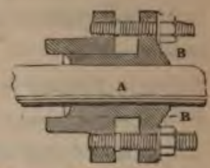
STRAP, a sort of bandage or fastening for securing the junction of two or more pieces of timber, consisting of a piece of wrought-iron, of a flat cross section, and extending over each piece of timber, according to circumstances, being bolted or keyed to them. The annexed cut represents a strap for tying three pieces of timber together, as in bridge-building; the ends of the straps are taken through a bottom plate, and made tight by means of nuts on the other side.

The straps employed in securing the bottom of king or queen-posts to tie beams, are termed *stirrups,* and are passed round the under part of the tie-beam, taken up on each side, and fastened to the posts by gibbs and keys.

STRETCHING-COURSE (in masonry and brickwork), a course consisting of all stretchers, or stones, bricks, or the like, laid lengthways in the longitudinal direction of the wall.—*See Bond and Heading Course.*

STRING-COURSE, a term applied generally to a course of masonry or brickwork, projecting in a slight degree before the face of the wall.

STUFFING-BOX, or GLAND, a piece secured to the end of a cylinder, pipe, or other vessel, through which a rod passes; a little hemp being pressed tightly against it, by which it is kept air or steam-tight. A in the cut is the piston-rod, and B the stuffing-box.



SURVEY, a measured plan and description of any line or area of country.

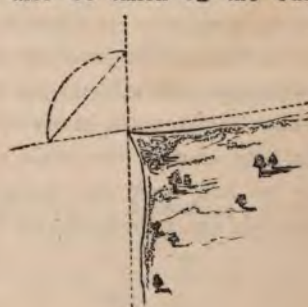
SURVEYING, the operation of making a survey, which is either performed by Gunter's chain, both angles and distances being taken with it, or the angles are taken by angular instruments, and the distances by a chain; the distances are also sometimes calculated, when the survey is said to be performed *trigonometrically*.

In chain surveying, the surveyor is confined to one figure, viz., a triangle, which should always be as near an equilateral triangle as possible; for when the angle at the top is either very obtuse or very acute, the most trifling error in the admeasurement of either of the sides will alter its figure, and consequently its area.

In order to explain generally the principles of surveying, suppose the plan of a piece of land is required, such as represented in the cut:—First erect a conspicuous mark at one corner of it, say at 1, then look to the opposite corner, and commence chaining in that direction, keeping the line straight by the eye, which may be effected by looking towards some natural object upon it; if you cannot find any, set up one at the further end, and leave some marks near the middle of your line, measuring their situations; these are for the purpose of running out lines or checks, and are termed *false stations*; upon reaching the extremity, commence running a line along one side of it, and take offsets to the boundary (*see Offsets*): upon arriving at the end, put up a mark, and commence another side-

line, taking offsets as before, which will bring you to the starting point, then measure a tie-line from the angle formed by the junction of the side-lines to one of the false stations left in the diagonal commencing the survey, which completes this side; the same system must then be pursued with the other, and in fact with the whole survey, of which this may be supposed to form a part; this plan of working is termed *surveying by diagonals*. The plan may also be taken by means of *chain angles* only; and it is much practised, although not so secure from error thus, (*see side Cut*): mark off any convenient length on each of the side lines, as 1, 2, or 3 chains, commencing from each station, and, by measuring the distance between them or the tie, the angle will then be obtained. It is not absolutely necessary to take more than one or two in a field, but if others are taken they would form checks to the work.

Chain angles and offsets may also be taken on the outside of the side lines instead of the inside, if more convenient; thus:—



The angles may likewise be taken with a theodolite or a sextant, instead of measuring them, if such instruments are at hand.

A road may be surveyed, sufficiently accurate for some purposes, by means of chain angles; the width of it, also the buildings, &c., upon each side being taken by offsets; and the commencement of any fences may be sketched or taken by chain angles.—(*See Cut on next page*).

A surveyor commences chaining by first noting his first station, he then sends his chainsman forward, who takes the further end of the chain in one hand, and the arrows (10 in number) in the

other, and when he arrives at the end of the chain he turns round and looks to the surveyor for instructions, who directs him to the right or the left, as may be required, by waving his hand; when the chainsman is got into the right position, he sticks one of the arrows in the ground at the end of the chain, where he leaves it, and again walks forward with the chain. The surveyor, on arriving at the spot where the arrow is fixed, places his end of the chain upon it, and directs the chainsman as before: he also takes up the arrow, and proceeds forward until in like manner he obtains all the arrows, when he returns them to the chainsman, making a note of it in his Field-book; he of course leaves such *false stations* in the line as he considers necessary; for instance, upon arriving at a fence, either upon one side or upon the other, which he also notes in his Field-book. In hilly country the chain ought not to be laid upon the surface of the ground, (as represented by Fig. 2, in

Fig. 1.

Fig. 2.

the diagram), but it should be laid horizontally, in short lengths, (as Fig. 1), a plumb-line being suspended from it. If the hill is very steep, it may be

chained straight, and the vertical angles taken with an instrument, and the requisite deductions afterwards made.

The following Table shows the quantity to be subtracted from each chain's length for various angles of inclination of the ground:—

Reduction in Links and Decimals upon each Chain's Length, for the following Angles of Elevation and Depression.

Angle.	Reduction.	Angle.	Reduction.	Angle.	Reduction.
° '	° '	° '	° '	° '	° '
3. 0	0.14	9. 0	1.24	15. 0	3.40
		30	1.38	30	3.64
4. 0	0.25	10. 0	1.52	16. 0	3.88
		30	1.68	30	4.12
5. 0	0.38	11.30	1.84	17. 0	4.37
		30	2.01	30	4.63
6. 0	0.55	12. 0	2.19	18. 0	4.90
30	0.65	30	2.37	30	5.17
7. 0	0.75	13. 0	2.56	19. 0	5.44
30	0.86	30	2.77	30	5.74
8. 0	0.98	14. 0	2.97	20. 0	6.03
30	1.10	30	3.18	30	6.33

The reduction for one chain multiplied by the number of chains will give the quantity to be subtracted from the measured length of an inclination to reduce it to horizontal measure.

Extensive surveys are usually performed by extending a series of triangles over the country to be delineated, and it is always best to refer to some former plan previous to commencing operations, if it can be procured; by which the surveyor will be enabled to see the best situation for his main lines, in reference to their junction and freedom from obstructions:—

The first, or base-line, should pass through the centre of the survey, and intersect the most intricate portions; upon determining which, set up a theodolite at its commencement, (which should be on some conspicuous land-mark, as a church, house, windmill, &c., and, if possible, within the extent of the survey); next ascer-

tain very correctly the angle formed by this line, with the magnetic meridian, then take angles to some conspicuous objects near it, in order to fix the exact spot for the purpose of future reference; next erect a high pole upon it, and commence measuring the line, driving stakes along it at distances of about 5 or 10 chains, and numbering them (the chain should be previously measured, in order to start with a correct standard); the roads, rivers, fences, &c., must also be noted, as they are crossed, and offsets taken to all conspicuous objects within distance and prominent points; poles must also be set up along it, occasionally, to keep it direct: in the event of meeting a house or pleasure-ground, through which circumstances prevent a line being run, measure an angle, of exactly 60° on either side, with the theodolite, and set out a sufficient length upon it to clear the obstruction, then take another angle of 60° from it, and measure the distance equal to the last, which brings you on the other side of the obstruction, and in the direction of the main line. If the poles set up are beyond the limits of vision, measure the supplementary angle of 120° from the last-measured side of the equilateral triangle, which gives the direction of the base, and check it by taking the bearing, which, of course, will be the same as at starting, if all is correct. Upon reaching the end of the base, set up the theodolite, and take the angle of one of the side-lines, which should not be very oblique, but as near 45° as convenient, it should also have some natural mark upon it, similar to the base-line;—the measurement of this angle being very important it should be repeated several times, and the mean of them taken; then set up a pole at this station, and measure the new line in a similar manner to the base, driving stakes at regular intervals, and upon arriving at the boundary of the survey, or as far as requisite, set up the theodolite, and take an angle to the opposite side of the survey, crossing

the main line and another angle to the starting point, or first station, then set up a pole on this station, and measure the transverse line as before, and upon the exact spot of crossing take the distance from the nearest stake previously left upon it, and terminate the line at the extremity of the survey, or as far beyond it as may be necessary, so that the tie-lines taken from it to the extremities of the base shall comprise the entire survey, excepting any small portions, which may be determined by small triangles from the principal ones, thus—the four principal lines may be said to be fixed, the internal lines may now be commenced, and run according to circumstances.

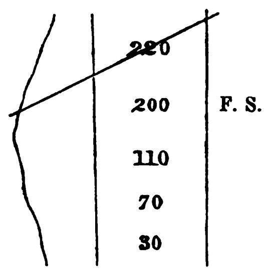
It may be stated generally, that it is best to finish one part of a survey before proceeding with another, as it prevents confusion; the boundaries should also be taken, and those parts without the tie-lines, previous to filling in any part of the plan, but if considered inconvenient, such parts only should be circumscribed where operations are about to be commenced.

It is advisable to take the angles of all lines, except those which are well tied; those determined by their extremities only should always be taken, for which the sextant may be used, and it is best for a surveyor to lay down or plot his work every day, as he proceeds with his survey.

The grand desideratum in all systems of surveying consists in obtaining a correct plan, with no more lines than are absolutely necessary, and the avoidance of passing backwards and forwards over the same ground, together with a clear method of keeping the Field-book, which should be as simple as possible; the system generally adopted is, to number all the lines of a survey, and measure the length of each, taking the bearings and offsets from them, as may be necessary; the Field-book being ruled with three columns, the distance and bearings are entered in the centre column, and the side columns are employed for noting down the offsets and breaks on each side, also for observations, sketches, &c. It is the custom to begin at the end of the book, and work up the leaf instead of down it, (as in levelling and ordinary observations), commencing at A, in the following diagram:—

68	12.00	50
70	10.20	55
81	9.00	48
72	8.00	42
21	7.20	40
30	5.00	42
50	4.00	40
55	3.20	35
30	1.00	38
	⊙ A	

The mark ⊙ means station, which are numbered as the survey proceeds; the figures in the centre column refer to the distance from the station at which the offsets have been taken, and they represent links, being the most convenient for plotting; the figures in the side columns show the length of the several offsets on each side, thus; it is 38 links at a distance of 100 links from the station to the fence on the right hand of the station, 35 at 320 links, and so on. False stations for subsequent operations are marked F. S., thus:—



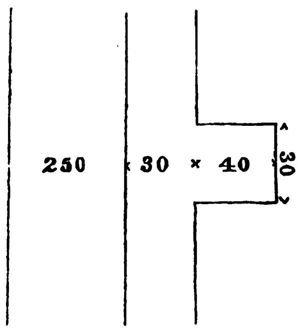
The F.S. occurs at a distance of 200 links from the station, and the figures 220 indicate that it is 220 links from the station or starting point to the fence.

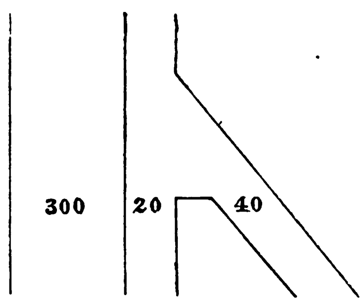
The commencement of a line is headed thus:—from ⊙ 2 (station 2) to right or left of base; or F. S. 200 (false station at 200 links) on last line; or from F. S. 15.20 to F. S. 23.15: if the line runs into another, and finishes in same, it is called a *close*, and marked accordingly at the end, as, close at ⊙ 6, or close at F. S. 700. The length from one station to another is called the

length of the line, which is designated according to the starting point, as the length of the first, second, or third station line. When the bearing is taken, as in the case of running a base, it is entered at the commencement of the line, as follows :—

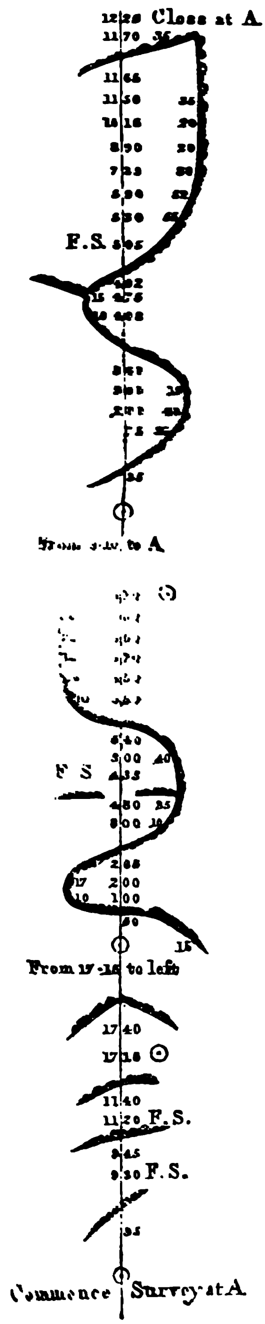
° ′ 69 0	N.E.
⊙ 6	

The following methods are also adopted for taking roads and angles :—

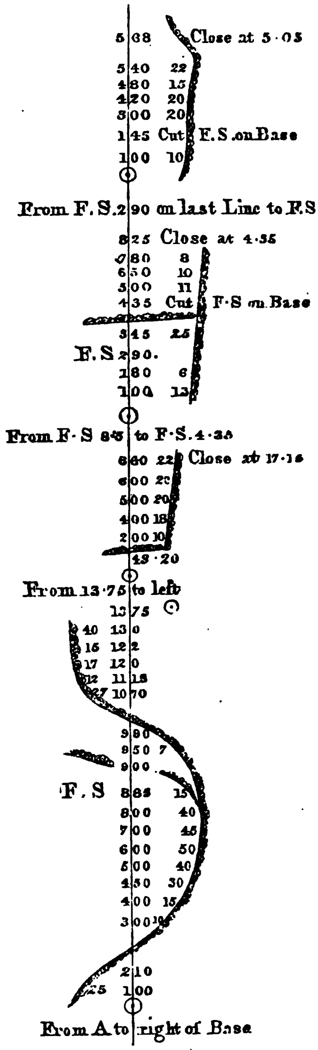


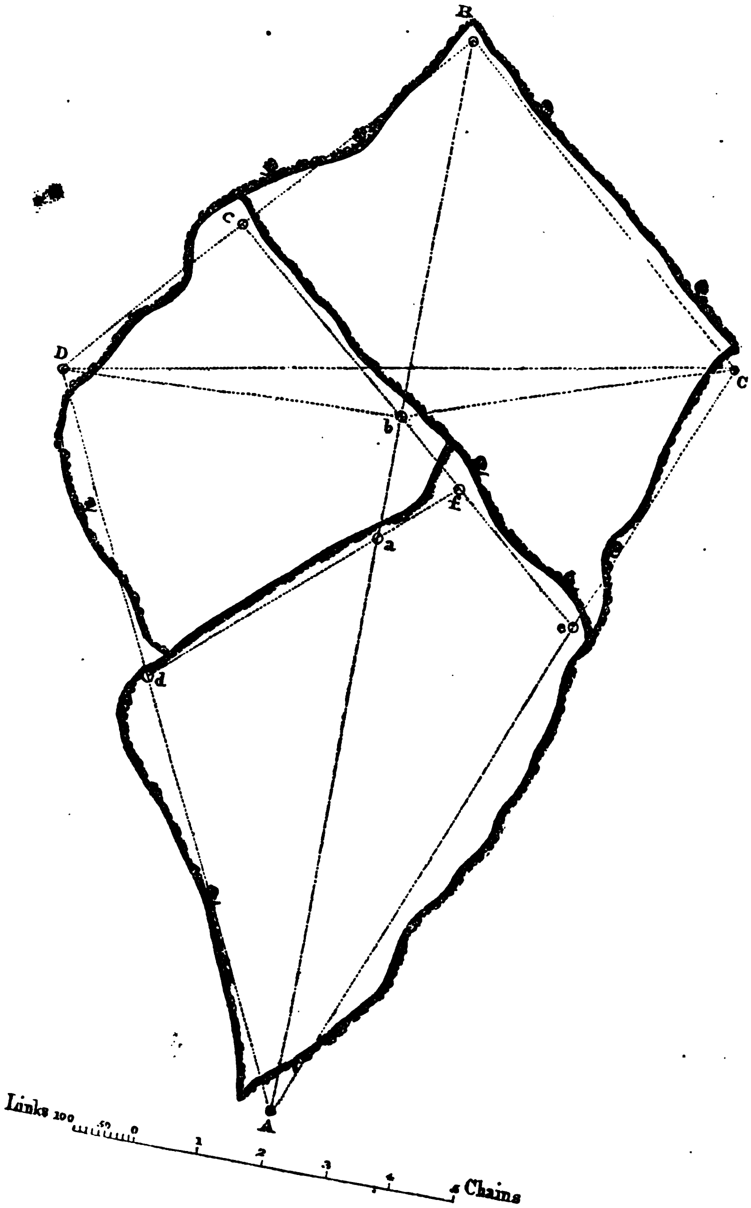


Some surveyors also sketch their plans in the Field-book, *i. e.,* they enter the several lines as they are measured, and the offsets in the order that they are taken, the system of commencing at the bottom, and writing upwards, being pursued the same as usual.


Close at A.
F.S.
From 17·18 to left
17 40
17 18
11 40
11 20 F.S.
9 30 F.S.
Commence Survey at A.

The following engravings represent two different forms of keeping a Field-book (page 264 and 265 constituting one, and page 266 the other), by Mr. Peter Bruff, each referring to the same plan, which is plotted at page 267, and either will be found very simple and efficient:—




B
C
c
D
b
f
a
e
d
A
Links 100
50
0
1
2
3
4
5 Chains

In plotting the work, the whole of the lines of the survey should be plotted before any of the fences are commenced, the several angles taken by instruments being laid down by a circular or semicircular protractor.—*See Plotting.*

In making subterranean surveys, as plans of coal-pits, mines, &c., a circumferenter is generally employed, the method of proceeding being to plant the instrument at the point of commencement, when the assistant walks forward in the proper direction, with a lighted candle in his hand, and takes his station, the bearing and distance of it are then noted; the instrument is next fixed on the spot where the candle was situated, and a second observation taken in a similar manner to the first, which system is pursued until the whole survey is completed.

The area of the land is calculated from the finished plot of the survey; and the lengths being taken in links, it is readily ascertained by multiplying them together, and pointing off five figures on the right hand, when those on the left (if any) will be acres; those struck off are then multiplied by 4, and five more struck off, the figures on the left will then be roods. The same principle may be pursued for the perches; thus, suppose the area of a piece of ground, 400 links long, and 260 wide, is required, then

```
   260
   400
 -------
 1|04000
       4
 -------
  |16000
      40
 -------
 6|40000
```

Area 1 acre, 0 roods, 6 perches.

If the ground is in the shape of a triangle, multiply the height by the base, and take off one-half the product for the area.

Large surveys are generally computed by dividing the whole into columns of equal width, say 1 or 2 chains wide, and every 5 or 10 columns may be also calculated together as a check, and a summary of each drawn out, when any errors will be detected.

The system of calculating the area of the columns is as follows:—Suppose the number of square chains in a column to amount to 108 (either a column 1 chain wide, with a length of 108 chains, or a column 2 chains wide, with a length of 54 chains), then bring it into acres, by dividing it by 10, the number of square chains in an acre; or otherwise cut off one figure on the right, it may then be multiplied for roods and perches, thus:—

$$\begin{array}{lr} \text{Number of squares in column} & 10|8 \\ & 4 \\ \hline & 3|2 \\ & 40 \\ \hline & 8|0 \\ \hline \end{array}$$

Contents of column, 10 acres, 3 roods, 8 perches.

The contents of the whole may also be computed by the measured lines, the computer equalizing and arranging such parts which may be on the outside into triangles and other regular figures. The inequalities of the boundaries may be equalized by the eye with sufficient accuracy, *i. e.*, an extra portion may be taken into the calculation in some parts, and a less area in others, corresponding to that allowed, by which the true area may be found; this may be effected by equalizing the boundary by a pencil, or by laying a thin piece of transparent bone, or a piece of glass upon it, remedying the irregularities by the eye.

Tables of the contents of various bodies are also very extensively employed at the present time.—*See Arrow, Chain, Theodolite, &c.*

Suspension Bridge, a bridge suspended from inverted bows, by means of rods, being usually formed of iron, at the present time; the bows are supported by stone piers erected at each end, and from thence carried down and secured in the ground.

Suspension bridges are generally adopted where the span is very great: the first notice of them appears to have occurred towards the end of the sixteenth century; the which were composed of cordage. The most celebrated suspension bridges in this kingdom are those erected by Mr. Telford, of which the Menai

Bridge is the most extensive, being 560 feet between the points of suspension, and 100 feet in the clear above high water-mark: four arches are built on one side of it, and three on the other, each of 50 feet span.

The bridge consists of four suspended cables of malleable iron, the versed sine of their curve being about 57 feet, or $\frac{1}{10}$th of the span, and two carriage-ways pass over it, each 12 feet wide, with a footpath between them, 4 feet wide. The weight of the bridge between the points of suspension, including the cables, is said to be 489 tons; and, as the suspending power is calculated at 2,016 tons, a disposable force of 1,674 is provided to meet any stress the bridge may encounter. This bridge has, however, recently sustained considerable damage, principally from the effects of high winds. There are likewise several other suspension bridges of great span erected; as that over the Thames, at Hammersmith, which is of 400 feet.

It is imagined by some, that chains introduced under the platform, in an inverted position to the principal suspension chains, would give greater strength to these bridges, and render them proof against the action of strong winds from beneath, and by

Elevation of the Bridge in the Island of Bourbon.

Plan of Ditto.

Victoria Bridge, Bath.

arching them on the plan, or fixing the chains a greater width apart at the piers, they would also be proof against side-winds, and thereby correct any rocking motion. The bridges erected for the Island of Bourbon, by Mr. M. I. Brunel, C.E., are constructed on this principle.

Colonel Pasley, R. E., attributes the injuries frequently sustained by suspension bridges during heavy gales, to their being generally constructed without any longitudinal trussing upon the platform, as he considers that the wind acts from beneath; the rise and fall of the Menai Bridge, which is not furnished with any, is stated to be above 3 feet in ordinary gales; but the Hammersmith bridge, having four ties of longitudinal trussing along it, is not so affected. This framing also serves as a means of enclosure to the footways.

The latest improvements in suspension bridges are comprised in Mr. Dredge's "*patent*;" and the Victoria Bridge, erected by him, at Bath, is upon this principle.

The construction of the bow chains will be readily understood by the following diagram, which exhibits the form of a portion of the bow chains of the Menai Bridge, and those of the Victoria:—

Bow Chains of the Victoria Bridge.

Bow Chains of the Menai Bridge.

The bow chains of the Victoria Bridge are tapered gradually to the centre of the bridge, and are thereby rendered much stronger at the points of suspension; but those of the Menai are formed of similar size throughout the centre portion, there-

fore, being overcharged, the superfluous weight assists the wind, and occasions the rocking motion before noticed; and those portions of the chain next the piers are deficient in strength to exactly the amount of the excess of the centre portion. The suspending rods are also fixed in an oblique direction instead of vertical, as in ordinary suspension bridges.—*See Bridge.*

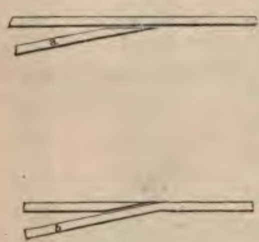
SWIVEL, or SWING BRIDGE, a moveable bridge much employed in docks, in order to admit of the passage of shipping, consisting of two parts, or platforms, their point of meeting being midway between the abutments; each portion turning upon a centre pivot, and supported upon rollers, on the same principle as a railway turn-table: the over-hanging portion is balanced and kept in the proper position by a counterbalancing weight, fixed within the framing at the other end.

The iron Swing Bridge, over the entrance-lock, at the West India Docks, by Mr. Ralph Walker, C.E., was among the first instances of this description of bridge. Timber turn-bridges are sometimes erected on canals; but iron is the best material for them, on account of its freedom from warping.

Swing Bridge, London Docks.

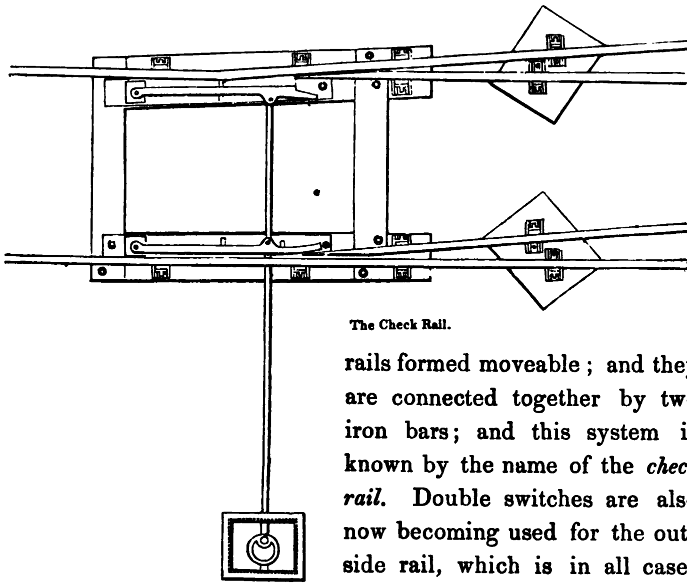
Side Elevation. Transverse Section.

SWITCH, (railway), that portion of moveable rails forming the junction of a siding with the main line, which are usually shifted by means of an eccentric movement, enclosed in a box. It has been the general custom to form them of the following form, on colliery railways:—*a*, being the *switch rail*, which is moveable, and *b*, the *check rail*, which is immoveable; and this plan of formation is distinguished by the name of the *switch rail*. The switches employed on



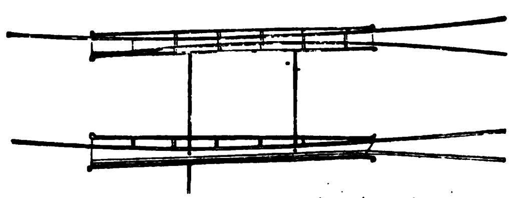
The Switch Rail.

the London and Birmingham, and some other railways, have both



The Check Rail.

rails formed moveable; and they are connected together by two iron bars; and this system is known by the name of the *check rail.* Double switches are also now becoming used for the outside rail, which is in all cases the guiding rail; and the inner rail continues through entire, according to Mr. Curtis' improved plan, thus;—



Curtis' Sliding Switch.

The inner pointed switch shuts against a solid, which renders the whole much more secure than in the common switch rail, and there is a counterbalancing weight connected with the lever handle, by which the rails are kept right for the direct line, which is an important advantage: moveable rails of this description are termed ***sliding switches.***

SYPHON, an instrument frequently employed in hydraulics, consisting of a bent iron tube.

The property of the syphon is, that when filled with water, and placed with the bend uppermost, each leg being situated in a separate basin of water, it will allow the water to pass through in one direction, but not in the other, viz., from the upper to the lower basin, as upon the air being exhausted from the lower, by any water situated at the level of the shorter one, it will move up and pass out at the longer opening.

TALLUS WALL, a wall battering on the face.—*See Retaining Wall.*

TEAMING, the operation of leading the earth or excavation from a cutting to the embankment.

The distance from whence the soil is dug, to the spot whence it is teamed, (commonly called the *head* of the embankment) is denominated the *lead,* or *haul;* and continually increases in length as the work proceeds.

TELEGRAPH, a machine for facilitating the communication between distant places, and supposed to be of great antiquity; although not perfected until modern times. A galvanic telegraph is laid down upon a portion of the line of the Great Western Railway, which is said to answer very well.

TEMPLATE, a sort of mould employed in cutting and setting masonry and brickwork. Templates consist of a thin piece of iron, cut to the exact cross section of the moulding or other feature to be worked.

TEMPLET, a short piece of timber sometimes placed on a wall, to receive the ends of a girder; they are more especially used in brick walls, as a large stone is found sufficiently efficacious in stone walling.

TENDER, a waggon built expressly for the purpose of accompanying a locomotive engine, for the conveyance of the fuel and water, the fuel being situated at the bottom of it, and the tank containing the water at the upper part.

The communication with the locomotive is effected by two

copper pipes fixed beneath the tank, one upon each side, and connected with elastic hose to the suction-pipes of the feed-pumps, which are worked by the engine. And some tenders have a steam-pipe laid on to them from the engine, to warm the water.

The supply of fuel and water carried by a tender depends upon the weight of the load, and upon the resistance offered by the road, and the rate and amount of the clivities upon it. Some carry sufficient to last from 30 to 40 miles, or about 700 gallons of water, and 8 cwt. of coke; but tenders are generally refilled at 18 or 20 mile lengths, and they mostly weigh about 3½ tons when empty, and 7 tons when loaded full; they are also usually placed upon four wheels, but when of very great weight they are frequently supported on six.—*See Locomotive Engine, &c.*

TENON.—*See Mortice.*

TENSION BRIDGE.—*See Bow-string Bridge.*

TERMINAL PLANE, the plane at each end of a line of railway. Terminal planes should always be upon a descent from the depôt or station, for the purpose of starting the *departure train,* and checking the velocity of the *arrival train.*

TERMINUS, the extreme point at either end of a railway.

THEODOLITE, an instrument used in surveying, for measuring both horizontal and vertical angles.

The theodolite is mostly employed in determining particular stations, and in running base-lines, being the most perfect of all angular instruments.

THROTTLE-VALVE, (in steam-engines) a contrivance to regulate the supply of steam to the cylinder, and which is brought into operation by the action of the governor in fixed engines, but in locomotives it is worked by the engine-man, by means of a lever-handle.

THOROUGH.—*See Perbend.*

TIDE, the rise and fall of the level of the water in rivers and seas, which occurs twice in rather more than 24 hours, and is attributed mainly to the influence of the moon. The height of the

tide on any particular day also depends upon the age of the moon; the highest tides being about the time of new and full moons, and the lowest when the moon is in her quarters.

The action of the sun also produces tides, but its effects are less on account of its distance from the earth being much greater than the moon. When the sun and moon are either together, or directly opposite to each other, viz., at new and full moon, the greatest influence of each occurs at the same hour, the height of the tide is thereby rendered greater than usual, and is termed a *spring-tide;* when, on the contrary, the moon is halfway between these two positions, or at the quarters, then at any place where it would be high water by the action of the moon, it would be low water by the action of the sun, the tide consequently does not rise so high as usual, when it is called a *neap-tide.*

TIDE, or GUARD-LOCK, a lock situated between an entrance basin and a canal, harbour, or river, and forming a communication between them. It is furnished with double gates, whereby craft can pass them either way, at all times of the tide.

TIDE-MILL, a mill connected with other machinery, and consisting of a water-wheel, which is put into motion by the ebbing and flowing of the tide. The wheel is sometimes made to rise and fall with the tide.—*See Water-wheel.*

TIMBER, a term applied to trees after they are felled. The trunk of a full-grown tree presents three distinct parts, viz., the *bark*, or exterior; next to which is the *sap;* and the centre of the tree, which is called the *heart*, and forms the most essential portion.

A period of full 3 years should elapse after the felling of a tree, before making use of it for building purposes, during which period it should undergo the process of drying, by being sawed into various thicknesses, as may be required, and properly piled.

Oak is a most durable and tough wood, and much used for all ground purposes, as sleepers, planking, &c.; it is exceeded by none for strength and durability, and is particularly well adapted to bear and suspend weights.

Elm is a wood often adopted for piles and the like, being

excellent when used under water, but it will not stand alternate dryness and moisture like oak. Beech is also used for piling.

Foreign fir is much employed in this country, Memel, Riga, and Dantzic being considered the best. American pine is likewise imported; the red pine being a favourite timber for piling.—*See Kyanize.*

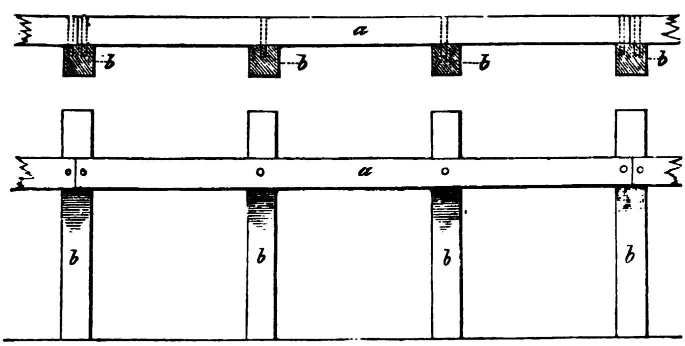
TRACTION, the amount of tractive power necessary to overcome the resistance upon a road, railroad, or canal.

TRACTIVE POWER, the power of draught required to overcome the friction or resistance of a road, canal, or railway, the amount of which, is regulated by the state of perfection of each respectively, and upon the construction of the vehicles to be propelled along them.—*See Road, Paved-way, Tramroad, Railroad, and Canal.*

TRAM, a local name given to coal-waggons, in the neighbourhood of Newcastle-upon-Tyne; hence the word *tramway* was given to the road prepared to receive them.

TRAM, or PLATE-RAILROAD, TRAMWAY, or TRACKWAY, a description of roadway consisting of narrow tracks, plates, or rails of wood or iron, the same being prepared to receive the wheels of carriages or trams, as waggons were formerly called, whereby the transit of the latter is much facilitated.

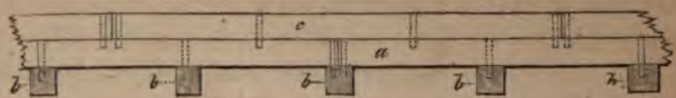
Details of a Single Way. Longitudinal Section.



Plan.

a, a, the longitudinal beams or rails.

b, b, b, the cross sleepers.



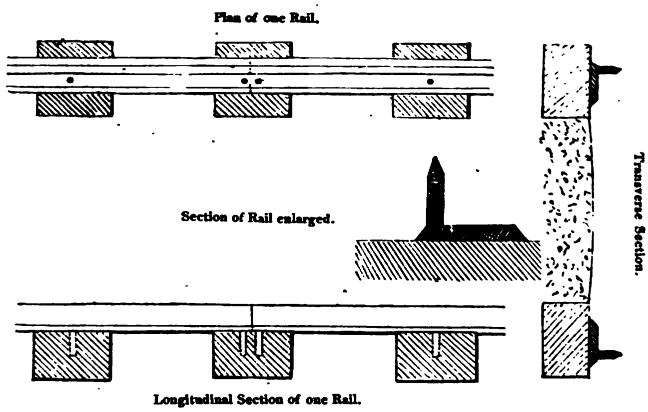
Details of a Double Way. Longitudinal Section.

Trackways were employed in this country as early as the year 1600, and were originally constructed of timber, the transverse sleepers being of oak or fir, from 4 to 6 inches square, 5 or 6 feet long, and laid about 2 feet apart. The longitudinal beams or rails laid across the former were generally of sycamore or larch, being secured thereto by pins or pegs of wood, and were from 4 to 6 inches square, and laid in about 5 or 6 feet lengths, and this description of line formed what was called a *single way*. *(See Cut on last page.)* When two longitudinal beams were laid one upon the other, it was called a *double way;* the which constituted a great improvement upon the former, the transverse beams were thus protected from the feet of the horses, as a space was obtained for ballasting, which was laid up to the bed of the upper rails, and the under rail was also protected by it; the upper one could consequently be replaced when worn, without disturbing the lower; the surface of some of these rails was square throughout their width, in others a small ledge was placed at the side, to keep the wheels in their places, similar to iron-plate rails, while some had all the edges rounded off like edge-rails, in which case flanges were placed upon the wheels of the waggons.

At the period of coal fuel becoming used in the metropolis generally, instead of wood, which occurred in about the year 1760, the demand for it caused a proportionate increase in the expense of conveyance, which led to the use of iron rails, as a means of reducing it, and wrought-iron plates, 2 inches by ½ an inch, having been occasionally laid upon the surface of the beams, and secured by counter-sunk bolts, at sharp curves or steep planes, to receive the wheels of the waggons, gave the first hint to the projectors. Cast-iron plate rails were first employed in the year 1767; the trams or beds were generally made about 3 inches

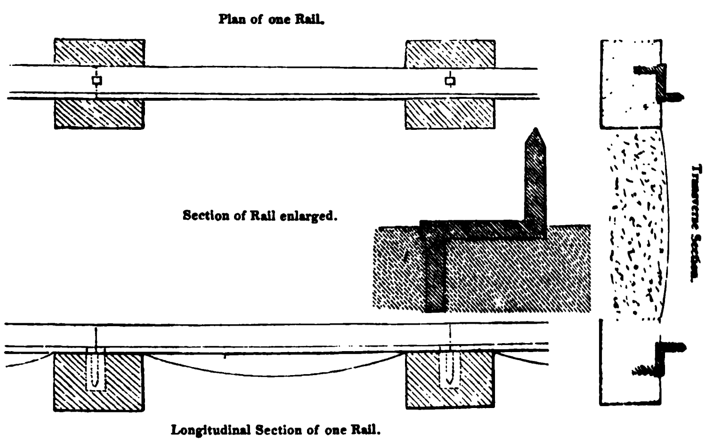
wide, with an upright ledge, 3 inches high, termed the *keel*, cast on the surface and upon the inner side, to keep the wheels on the tracks, and they were usually cast in about 6 feet lengths, and secured to the sleepers by spikes and oak plugs.—*See Cuts below.*

Details of a Tramway with a single Flanche.



Edge-rails were first introduced in the year 1824, and are those in general use at the present time. Although tram-rails form a very excellent road, when properly laid down, yet they are not

Details of a Tramway with a double Flanche.



equal to edge-rails. There are several modifications of them—some have a circular flange or web on the outer edge, projecting downwards, which increases their strength much, and the rounding of the inner angle formed by the meeting of the tram and keel is also an improvement, as it reduces the friction.—*See Cut on last page.*

Tramways are yet much used for both permanent and temporary purposes, in collieries, mines, and quarries, and in the formation of roads, railroads, and for other purposes, as the ordinary carts and waggons may be run upon them; and they derive some support from the ground between the bearings, which is rammed beneath the plates; indeed they are frequently laid upon the bare ground, when employed for temporary purposes.

There is a tramway from Wandsworth to Croydon and Merstham, formed of plates of cast-iron, $4\frac{1}{2}$ inches wide, and 1 inch thick, and laid in 3-feet lengths; the plates have an upper vertical guide-flanche, 2 inches high, and a fish-bellied lower flanche on the other side. The guide-rails are 4 feet apart, and the space between each line is 5 feet; the plates are bedded on stone blocks, and fastened down by iron spikes driven into wood plugs, which are let into the blocks vertically. Horses are used upon the line; the usual load of a horse being about 4 tons, the waggons weighing each 1 ton.

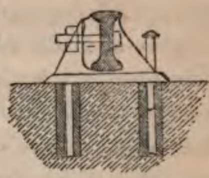
There is also a tramway at Glasgow, part of which is laid at 1 in 20, upon which a horse can drag 4 tons, and the amount of repairs upon it is very trifling: the trams are 8 inches wide, 2 inches thick, and are made in 3-feet lengths.

Tramways are sometimes constructed of stone, which description of road we have designated "Paved-way," for the sake of distinction, and described under that head. Many of the American railways are constructed of granite or hard stone sills, with flat bars of iron laid on them, to diminish the wear and tear; which plan has been found to answer very well.—*See Railway, Edge Railway, and Paved-way.*

TRANSIT INSTRUMENT, an instrument employed in the formation of tunnels, for the purpose of ranging the shafts straight together;

it is fixed upon a brick pillar, carried up solid from the ground, and quite independent of the building covering it.

TRENAIL, a wooden pin employed in timber framework, in situations where iron bolts are considered objectionable.



TRENAILS, or PLUGS, the hollow oak pins usually driven into stone blocks, when any thing is required to be secured to them, as the chairs employed on railways; in which case iron pins are first passed through the seat of the chair, and then driven tight into the centre of the plugs, which are generally 6 inches long, and $2\frac{1}{4}$ inches diameter, and formed of good heart of oak, or African oak.

TRUCK, as applied to railways, a stage or platform running upon wheels, and used upon railways for the conveyance of ordinary stage coaches and carriages, which are placed upon it. The mails, and most of the coaches remaining in the line of the several railways, are thus conveyed, the passengers and luggage keeping their respective places.

TUBE, a hollow cylindrical body.—*See Pipe.*

TUNNEL, a subterraneous gallery or passage excavated or dug through the earth for the passage of a canal, road, or railway.

The tunnel on the canal at Languedoc, in France, commenced in the year 1666, is one of the first instances of this description of work, although the principle is doubtless of much greater antiquity. The Hartshill Tunnel, on the Chesterfield Canal, and the Sapperton, on the Thames and Severn navigation, are among the earliest applications of the principle in this country—the former is 3,000 yards long, and the latter is $2\frac{1}{2}$ miles, and lined with masonry throughout; there are also some canals in this country communicating with coal mines, executed in tunnelling, and that to a very considerable extent.

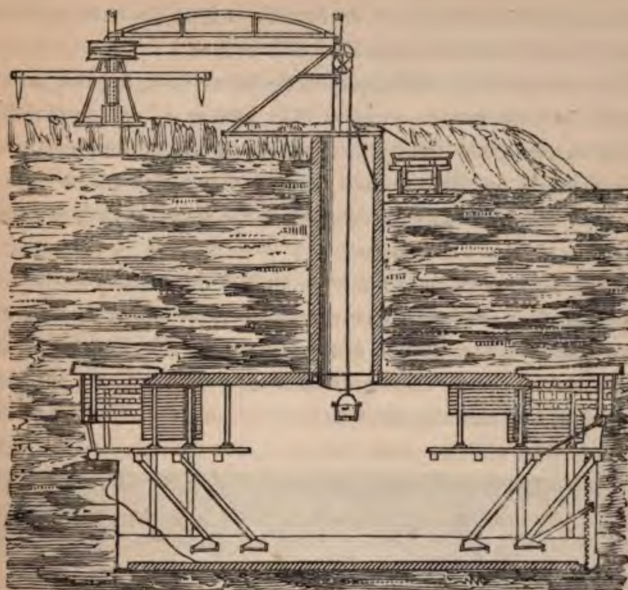
The tunnels already formed, or forming, upon the several railways at the present time, are generally made by sinking vertical working shafts, and then commencing abreast each way, upon arriving at the proper level; smaller shafts, termed *air-shafts*, are

also made, for supplying the tunnel with air: the excavation is formed as nearly the size of the tunnel as possible, the sides and top being supported by timber centreing, consisting of *leading ribs*, &c., also by shoars. The brickwork and earthwork are carried forward simultaneously, or as nearly so as possible, and usually in lengths of about 20 feet; and when the brickwork of a length is completed, the leading ribs are struck, and pushed on further for another length: the striking or slackening of the ribs is attended with some degree of danger to the brickwork, if due caution is not used; the space between the back of the brickwork of the tunnel and the excavation is carefully filled in with earth, and well rammed, and if any of the timbers should be found difficult to withdraw, they are allowed to remain. The soil of the excavation is drawn up the shaft to the surface of the ground by a horse-gin, which is fixed at the top. It is generally the practice to set a strong curb in the crown of the tunnel under a shaft, to support it, and cast-iron is at present used for this purpose.

The following cuts represent a portion of the Primrose Hill Tunnel, on the London and Birmingham Railway, during the course of execution, and which was constructed by the method before stated:—

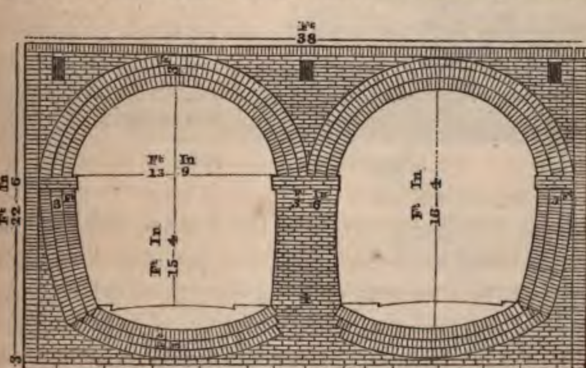
Transverse Section of Tunnel.

Tunnels are also sometimes worked by horizontal shafts, or galleries, as that taken through the cliffs at Dover, on the South-Eastern Railway; they are also formed in cuttings similar to bridges, the ground being shoared up on each side, and again covered over with earth upon the completion of the brickwork, technically termed *open tunnels*; an inverted arch is generally unnecessary in this description of tunnel, although always formed at the bottom of those of the former description.



Longitudinal Section of Tunnel.

The Thames Tunnel, between Rotherhithe and Limehouse, now in the course of execution, by Mr. M. I. Brunel, forms a most

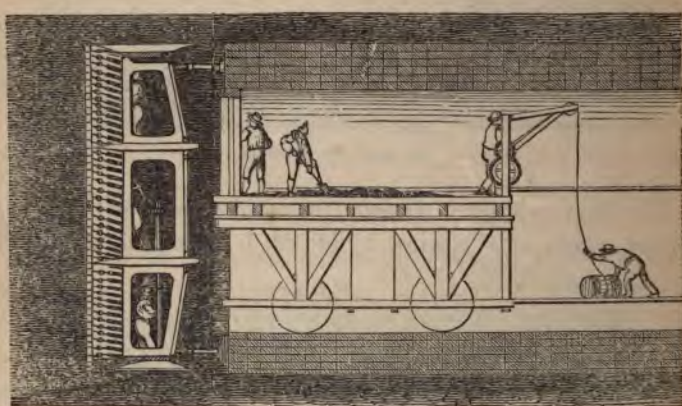


Transverse Section of the Thames Tunnel.

surprising instance of tunnelling; it consists of a double gallery, the width of the brickwork externally, including both galleries, being 38 feet, and the height 22 feet 9 inches.

The centre wall is built up quite solid at first, for the sake of security, and afterwards pierced with arches of communication; the works are conducted by means of an immense framing, termed a *shield*, which is divided into several compartments or cells, in which the miners and artificers are placed, and it is made to move forward as the work proceeds.

This cut represents the miners and bricklayers at work in the shield, which is moved forward by means of the horizontal screws, shown at the top and bottom of the tunnel, the moving stage which follows the shield is also represented, upon which the materials are placed, and the soil thrown:—



Longitudinal Section of Thames Tunnel.

There are several tunnels upon the London and Birmingham Railway, of which the Kilsby was found the most difficult to execute, one-fourth of its length passing through an extensive quicksand, which required the constant action of 2-28 horse power steam-engines for pumping, independent of other pumps for removing the water. The general size of the several tunnels on this

line is 24 feet wide, and 27 feet 4 inches high from the invert to the crown of the arch, and they are 24 feet 4 inches from the surface of the rails to the crown.—*See Shaft.*

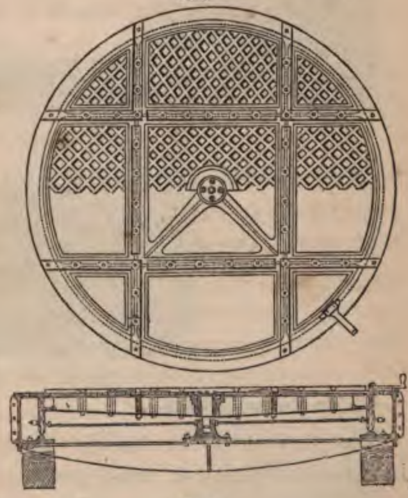
TURN BRIDGE.—*See Swivel,* or *Swing Bridge.*

TURN-OUT.—*See Siding.*

TURNPLATE, or TURNTABLE, a contrivance for removing railway carriages from one line of rails to another; they are generally made for crossings at right angles with each other, but can be adapted to any angle that may be required.

A turnplate is composed of iron framing, upon which iron gratings, or wood planking is laid, thereby forming a table or platform, two pair of rails being fixed on the upper surface of it, crossing each other at right angles, and of a corresponding gauge with those laid down upon the line. The platform is made to turn upon a centre pivot, which rests upon another iron frame, set on masonry; friction rollers being inserted between this frame, and that supporting the platform, which are situated at the edges of the table, and either secured to the circular curb, which encloses the table, or connected with the centre socket by iron rods.

A Turnplate on the London and Birmingham Railway.
The grating is removed in the lower half
Plan.



Section.

The size of turnplates is regulated by the length of the engines employed on the line of railway: they are 12 feet diameter on the London and Birmingham Railway; but they are made only 8 feet on some railways.

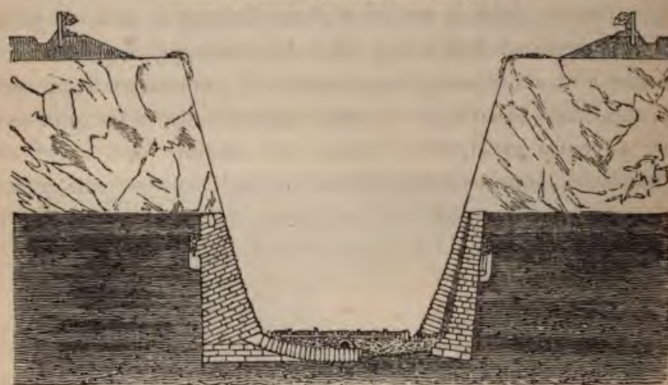
UNDERPINNING, the operation of making additions or repairs

to the foundations of walls, in which case the latter are supported by strong timber shoars and needles.

UNDERSETTING, the operation of supporting the earth in a cutting, when occurring below rock; and it is effected by the stone quarried from the rock, which is laid in courses against the face of the soft soil, the rock being formed as nearly perpendicular as considered safe and convenient to work.

The great Blisworth cutting, on the London and Birmingham Railway, is a good specimen of this description of work.

The Blisworth Cutting, London and Birmingham Railway.



Transverse Section.

A portion of the Plan.

VANE.—*See Fly-wheel.*

VALVE, a sort of moveable cover to an aperture, and occurring in various mechanical contrivances. Valves are used to separate two different elements, or bodies, and act by the force of that which is the most powerful, which is regulated accordingly: it

is also necessary that a valve be well made, so as to move on the application of a very small degree of force.

Valves are constructed in a variety of forms; but they may be described generally as being of four kinds, viz., 1st, those of the revolving description, comprising all cocks, from that in common use to the four-way cock employed in steam-engines; 2ndly, sliding valves, as the D slide valve, which is employed for a similar purpose to the last stated; 3rdly, the lifting kind, as the safety valve in general use for steam-boilers; and 4thly, the hinge class, as the clack-valve, which moves similar to a hinge. The two last classes may be said to act in a somewhat similar manner.—*See Air-valve, Clack-valve, D Valve, Four-way Cock, and Safety Valve.*

VERNIER, a contrivance connected with a graduated scale, and employed for measuring any portions of the space between the most minute dimensions. Verniers are applied to most of the optical instruments used in surveying.

VIADUCT, an elevated erection, usually consisting of a series of arches, and very similar in appearance to an aqueduct, but constructed for the conveyance of a road or railway, instead of a canal or other body of water.

VOUSSOIRS, the stones forming an arch, the beds radiating towards the centre or centres forming the curve. The centre voussoir of an arch is called the *key-stone.*

WAGGONS (railway); the form of carriages used upon railways depends, in a certain degree, upon the description of goods conveyed by them, although the same form of wheels, axles, and bearings, are common to all. The bodies of the waggons first employed were in the form of an inverted pyramid, or the shape of a hopper, being much wider at the top than the bottom; and this form is still retained for coal waggons and the like.

The wheels of some of the waggons employed upon the old wooden railway had flanges on the edges, similar to those used on edge rails at the present time; and as most of the colliery railways descended

towards the depôts, the fore-wheels were made of greater diameter than the hind ones, according to the angle of the road, in order to keep the bodies in a horizontal position; and this system has been gradually given up, all four wheels being now made of similar size. The modern coal waggons are about 8 feet long by 5 feet 6 inches wide at the top, and 4 feet deep; which size will contain 2 tons 15 cwt., or nearly 3 tons, by heaping the coals up.

The bodies of the waggons, upon the Newton and some other railways, are suited both for railway and common road travelling, which is very economical and convenient.—*See Axle, Bearing, and Wheel.*

WALL, a solid structure, composed of either stone or brick-work, being usually carried up perpendicular, and of various thicknesses, enclosing and supporting other works; the front surface of a wall is usually termed the *face*, and the stones or bricks forming it the *facing;* the inside is the *back*, or *tail*, and the materials composing it, the *backing;* the interior, or space enclosed, being called the *core*, or *filling in.* The face of a wall is sometimes sloped, the latter being termed the *batter.*—*(See Batter).* A wall is carried up in layers, called *courses;* if the courses are of equal thickness throughout, the term *regular coursing* is applied to them, and if unequal, they are called *random courses:* the system of laying the stones in the several courses forming a wall, is termed the *bond.*

The principal cause of decay in most structures arises from the unequal settling of the walls, which creates cracks and bulges in them, as they are not usually calculated to resist lateral strains, but are mostly built with a view of sustaining vertical pressure only.—*See Bond.*

WAREHOUSE, a strong erection formed for the reception of various description of goods.

WASHER, a piece of iron used in connection with a bolt.—*See Bolt.*

WASTE WEIR, a cut constructed through the side of a canal, for carrying off any surplus water that may not be necessary for

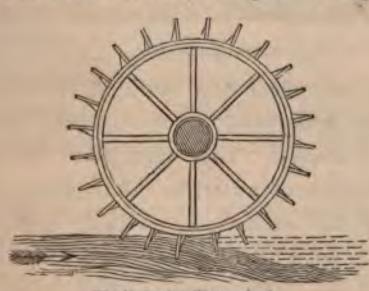
the navigation at certain times and seasons, operating as a drain. The front of the cut next the canal is generally faced with masonry, which is carried up solid from below the bottom of the canal, to the level of the pond at that part; therefore, when the height of the water exceeds this, it escapes into the cut, and hatches, or stop-planks, are fixed in the wall, to dam it off, when necessary.—*See Weir.*

WATER STATIONS (on railways), a small reservoir of water upon a line of railway, consisting of a tank, connected with a well. There is only one water station upon the Liverpool and Manchester railway, between the termini, a distance of 29½ miles, which is at Newton, where the trains stop.

WATER-WHEEL, an hydraulic machine employed in connection with mill-work, filling the situation of prime mover, it being the instrument whereby the motion of the water in a river or stream is brought into action.

There are four descriptions of water-wheels; viz., 1st, the *undershot*; 2nd, the *overshot*; 3rd, the *breast* wheel (each of which receive the impulse of the water vertically); and, 4th, the *horizontal*, upon which the water acts horizontally or bodily.

The undershot water-wheel is the most simple in action, and was in use long before the others, being the cheapest and readiest

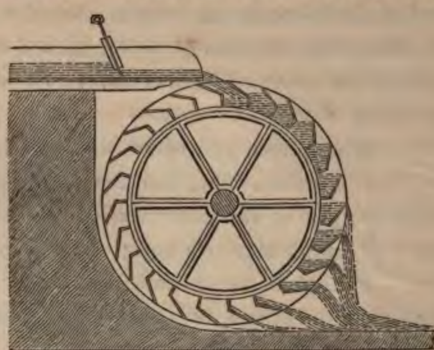


The Undershot Water-wheel.

for small streams in their natural state; and it may be used almost without any fall in the stream, provided there is plenty of water and a good current, as it acts principally by the momentum, and not by the weight of the stream; it also answers equally well both

ways, which renders it very suitable for tide rivers. The undershot wheel works best where the difference between the ebb and flood is not very great, as it should not be immersed in the water much beyond the width of the float-boards, on account of the loss of power occasioned by the action of the water upon them when returning upwards, after having passed through the lower part of the wheel-course; but if adopted under such circumstances, the diameter of the wheel should be made sufficiently large to allow of a small segment only of its circumference being covered by the water.

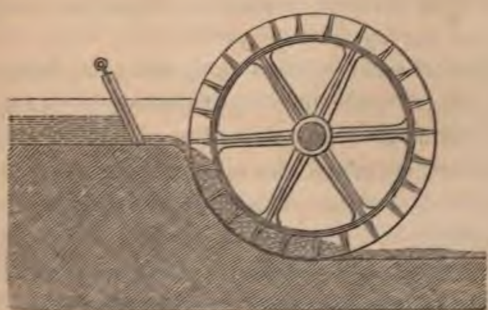
The overshot wheel is usually made in the shape of a drum, upon which a series of buckets are constructed, the water passing



The Overshot Water-wheel.

over the top of the wheel into them; it therefore acts by the gravity or weight of the water in the buckets, as well as by the mometum of the *stream.* This plan gives the greatest power with the least expense of water, as the thickness of the stream is seldom more than half an inch, or an inch; a penstock or sluice being fixed at the head of the wheel, in a proper trough, which regulates the supply. The overshot wheel requires a fall in the stream equal to rather more than its own diameter, which renders it necessary to make it of greater length in proportion to its height than is usual with other wheels. Its power is calculated at double that of the undershot wheel.

The breast wheel is a medium between the two former, and consequently much the most general; but, like the overshot, it requires a considerable force in the stream, and thereby also destroys it for the purposes of navigation. The water usually strikes the wheel at rather below the axis, although sometimes situated above it, and either floats or buckets are employed to receive it; the former are mostly adopted, and no water is allowed to escape past the mill-course without first operating upon them, there being no space left between: the supply of water is regulated by a penstock, as in the last description. The breast wheel consumes about double the quantity of water of the overshot wheel, in performing the same quantity of work; the diameter of the wheels, number of float-boards, &c., being similar in both cases. This method is the most suitable when the fall is between 4 and 10 feet; when it exceeds the latter, it is best to divide it into two falls, and the supply of water must of course be ample in either case.



The Breast Water-wheel.

It is a very essential point with every description of water-wheel to get rid of the *tail*-water, or that which has acted, and is consequently discharged at the bottom of the wheel, as the power of the wheel is considerably reduced by its accumulation; two small culverts or drains are sometimes employed to effect it, which are made in the masonry, passing from the head of the wheel to the tail-water, when the impetus of the stream rushing from the upper

pond down these drains will be found to carry off the spent water very effectually; a penstock should also be placed at the top of each of these culverts, in order to cut off the escape of water in dry seasons, or when scarce.

In situations where the supply is large and the fall little, an undershot wheel may be used; if, on the contrary, the fall is large and the supply small, the overshot is most appropriate; and in cases where the height of fall and quantity of water is but moderate, the breast wheel should be adopted. An undershot wheel works best when its circumference moves with between a $\frac{1}{2}$ and a $\frac{1}{3}$rd the velocity of the stream, but overshot wheels are not influenced by it, as all the buckets have to be filled in succession. Mr. Smeaton determined on 3 feet per second as the best velocity of fall for the latter, the distance from the spout to the receiving bucket being two or three inches.

The full power of a stream should always be taken advantage of in the construction of mills; a wide wheel of small diameter is best where great speed is required, if otherwise, a large narrow wheel may be employed.

The horizontal water-wheel is rarely met with, being very inferior to the former, on account of the resistance offered by the float-boards in returning against the stream, and other defects. Mr. Robert Beatson suggested the employment of suspended float-boards, which should present a surface for the stream to act upon in passing down, and allow the water to pass between them in returning upwards against the stream, the principle being similar to that of his patent horizontal windmill.—*See Windmill.*

There is also another form of water wheel, termed "*Barker's Mill,*" from the name of the inventor, which, however, is rarely employed; the water passes down a tube placed vertically, and escapes from a cross tube at the bottom, through two apertures placed in opposite directions of its extremities, and the engine acts by means of the reaction or counter pressure of the issuing water, when the lower tube is caused to revolve horizontally, and the whole machine with it; a vertical axle being placed within the

vertical tube, which gives motion to a horizontal one at the top by means of a pinion.

The propelling wheels of steam boats are termed *paddles*, the intent of which differs from the wheels before described, as they act upon the water, using it as a resisting force, whereas the former are acted upon by the water, *i. e.*, by the motion of the stream.

WATER-WINGS, the walls erected on the banks of a river next bridges, to secure the foundations from the action of the current; they are usually battered towards the stream, having good puddle filled in at their backs, and are sometimes further supported by sheet piling at the feet; they are usually executed in curved lines, the water-way being contracted at such parts.

WATER-WORKS, the name applied to all description of works employed for raising or sustaining water, as water-mills, wheels, sluices, and various other hydraulic works; but it is not generally understood at the present time to refer to any other than works erected for the purpose of supplying cities and towns with water for the daily use of the inhabitants.

The water for the supply of cities and towns is generally obtained from the neighbouring rivers or streams, and pumps are employed in forcing the water to the requisite height, which are worked by powerful steam-engines; where there are no fresh-water rivers within reach, the water is procured from wells, and the power required in this case is stated by Mr. Wickstead to be double that of the former: the water is also sometimes conveyed from the rise or upper portion of a river, by a small cut or canal; and as the velocity requisite for the water in the cut is small, compared with the usual run of rivers, the level of the cut at its termination is consequently higher than that of the river, and upon being taken a sufficient distance the required head of water may be thus obtained. The New River, London, is formed upon this plan, although it is said to be generally the most expensive in carrying into execution, but the annual expenses are less than where steam-power is employed in maintaining the required head

of water. If there are good springs of water in a town, and they are situated at a sufficient elevation to supply the houses, the cost will be trifling, compared with any of the above-mentioned systems; but it is an occurrence which rarely happens.

The water is frequently conveyed a considerable distance in iron pipes, through large cities and towns, on account of the number of houses to be supplied: the principal pipes are called *mains*, or *main pipes*, which communicate directly with the reservoirs, and are laid down in the principal streets only, and pipes of smaller bore, termed *services*, or *service pipes*, are connected with them, for the use of the remaining streets; a cock is placed at every such branch, whereby the communication with the main is either opened or closed, the latter being always charged with water, and there is a small lead pipe laid on from the services to each house or tenement requiring water.

The cocks of the services situated at the most distant parts are kept open a longer time than those near to it, in order that the whole district may have an equal supply, the velocity of the water at the extreme parts not being so great as where near the source: for when water is forced through pipes, either by a natural or artificial head, or by steam, or any other power, friction is created according to the velocity of the water, and the distance which it travels in the pipes; therefore if the power be not increased, the velocity of the water is lessened as it proceeds forward.

In small towns one line of pipes is generally found sufficient, and there are small lead pipes laid on to it, as with the former; the whole of the houses therefore receive an equal supply, and at the same period of time.

There are *fire-plugs* made on the several mains and services, at certain distances, which consist of holes about 2 inches diameter, into which wooden spigots are driven; they are easily removed in case of fire or frost, and the whole force of the water may be directed to one spot, by closing the service-cocks in the surrounding portions of the district.

The ancients employed lofty aqueducts for the conveyance of

the water intended for the supply of cities, and it has been stated that they were ignorant of the circumstance of water situated in pipes, rising to the level of the reservoir connected with them; the comfort and convenience of having pipes laid on to every house, as provided at the present day, was also unknown to them, at least the superior habitations only possessed it, the means of casting or constructing large iron mains being then unknown.

The conveyance of water for the use of the inhabitants of the city of London, and the general purposes of consumption, was first introduced in the year 1236, being brought from Tybourne; after which period stone conduits began to be used, which were at first lined with lead.

The Chelsea Water-works are among the most extensive: the supply is first received from the river into a large reservoir, 100 feet by 70 feet, and 10 feet deep; it is then passed into another, which is lined with stone and brick; from thence it is pumped into two reservoirs, paved with bricks, laid edgeways—the southern one is 300 feet by 100, and the northern 540 feet by 140; and their level being high, the water gravitates downwards, passing through filtering beds, which are of great extent, the southern one being 240 by 180 feet, and the northern 351 by 180 feet, and the level of the latter is kept higher than the other: the surface of these beds is composed of sand, and disposed in ridges, presenting an undulated appearance; their sides rise about 12 feet above the surface of the ground, and are strongly embanked and turfed over; the water is let on to the beds at several places, the ends of the pipes being fitted with curved boards, to diffuse the currents of the water, and prevent the surface of the sand from being disturbed; the bottom is formed of clay, 18 inches thick, to keep out the land-springs, and tunnels or culverts, 3 feet in diameter, and about 18 inches thick, are laid upon same, extending from one end to the other, viz., nine upon the northern, and eleven upon the southern; they are built of cemented blocks of brickwork, with the joints partially open; the heading joints

are quite open, and every alternate brick is omitted, the water is thus enabled to pass through them; a covering of gravel stones is then laid over the whole, 2 feet thick, upon which is a 6-inch layer of shelly concrete, next a bed of coarse sand, and, lastly, one of fine sand; the two last occupying a depth of about 5 feet: wooden troughs, 3 feet by 6 inches, and 3 feet deep, are placed between the tunnels, and about 10 feet apart, which prevents the water from washing the sand into holes upon its admittance into the filterer.

The deposit left upon the surface acquires a thickness of 1 or 2 inches in about three or four weeks, when about one inch of it is raked off, the remainder tending to improve the filtration by rendering the interstices less: the grosser portions of silt slide down the ridges, and are easily removed. It has been ascertained that the sediment does not penetrate through a greater depth than from 6 to 9 inches, according to the state of the Thames water, the greatest occurring during the prevalence of land floods in the river.

Upon the water having passed through these filterers, it is received in an open culvert, 15 feet deep, and is from thence conveyed to the mains: a steam-engine of 120 horse power is employed in raising the water; 3,500 gallons of which is raised per minute, or upwards of 5,000,000 gallons per day. The expense of these works is said to exceed £60,000.

According to a Parliamentary Commission, appointed a few years back, to enquire into the subject of the supply of water to the metropolis, the average quantity supplied was stated to be 170 gallons to each house daily; but it must be remembered, that very few of the cisterns are empty when the water is on, therefore nothing like that quantity is consumed. Mr. Tredgold states that the supply of water to a town should be 10 cubic feet per day for each house, exclusive of other demands, as for manufactories, breweries, watering streets, &c., amounting in the whole to 4 cubic feet per day for each person; in small towns $2\frac{1}{2}$ cubic feet is

sufficient. He also gives the following Table, which may afford some criterion :—

Towns.	Inhabitants.	Supply of water per day.	Each person per day.
		Cubic feet.	*Cubic feet.*
London	1,225,694	3,888,000	3.15
Edinburgh (old service)	138,235	80,640	0.61
Rome (modern) . . .	136,000	5,305,000	39.0
Rome (ancient) . . .	1,200,000	10,500,000	9.0
Paris	713,765	293,600	0.42
Plymouth	21,570	33,400	1.56

WEIR, an erection carried across a river or rivulet, for the purpose of damming up the water for the convenience of irrigation, and for other uses.

Weirs are formed of stone and brickwork, or of timber, being composed of frames placed side by side, in which stop-planks or hatches are dropped, by which the head of water is supported; cast-iron is also sometimes used for the paddles and framing: a single frame is, properly speaking, a *sluice;* it requires a series of them to constitute a weir.—*See Dam and Waste Weir.*

WELDING, the process of uniting or joining two pieces of iron together by the aid of heat and pressure.

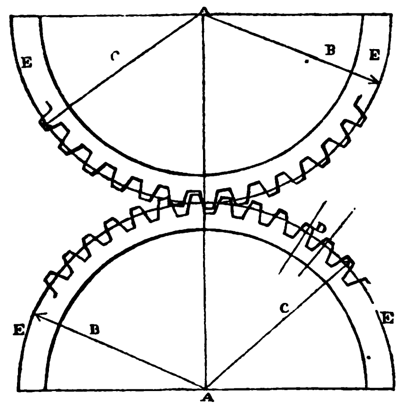
WELL.—*See Artesian Well.*

WELL-HOLE, a hole connected with some mechanical contrivances, and adapted for the reception of a counterbalancing weight, and for other purposes.

WET DOCK.—*See Dock.*

WHEEL, an agent very extensively employed in machinery; the wheel, with its axle, constituting one of the mechanical powers. Regarding toothed wheels, it may be stated, that they are described generally as *cog-wheels;* although the term *cog* bears more immediate reference to one of the teeth *fixed* upon the circumference of a wheel, the same being originally made of wood: when they are formed upon the body of the wheel, or both out of one piece, they

are termed *teeth;* and the teeth of a pinion are called *leaves*, and those of a trundle, *staves.*



In the case of two cog-wheels in contact with each other, as represented in the cut, the radii up to where the teeth commence, B, B, is called the *proportional radii;* a line joining their centres, A, A, is called the *line of centres;* and the distances to the extremity of the teeth, C, C, is called the *real radii;* the distance of the teeth from centre to centre, D, D, is called the *pitch* of the wheel; and the circles from which each commence, E, E, the *pitching line.*

A wheel which acts upon another, is termed a *driver* or *leader*, and the wheel acted upon, the *droven* or *follower.*

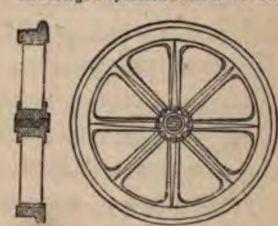
WHEEL (of a carriage), a solid disc or circular frame, constructed of wood or metal, turning upon an axis, and used for facilitating the conveyance of carriages. It consists of three parts, viz.,—1st, the *nave,* hub, or centre; 2nd, the *periphery,* or outside ring, being usually formed in circular pieces, termed *felloes;* and 3rd, the *spokes,* or radii, which connect the former together.

The peripheries of roadway carriages are encircled by *tires,* formed of flat bar-iron, made in pieces, and secured by nails passing through the felloes, with nuts and washers. The best sort of vehicles have the tires of the wheels made in a single piece or

ring, which being put on in a hot state draws and binds the whole firmly together by the contraction of the metal in cooling. The common practice of making the rims of wheels conical is highly injurious to the roads, as it gives the wheels a tendency to move out of the line of draught. The plan of rounding the extreme edges is less objectionable: but flat edges, or wheels perfectly cylindrical, are much the least destructive: they also run much lighter than the former.

The wheels of railway carriages were originally made of wood, which material was retained for the wheels acted upon by the brake long after the introduction of cast-iron wheels, as it was supposed to afford a greater degree of adhesion; but metal having been found to answer equally well for that purpose, iron is now adopted for the whole of the wheels. The next improvement was that of case-hardening the peripheries of the wheels, which arose from the great injury they sustained (and consequent increased wear and tear) upon the introduction of edge-rails: this plan also reduced the resistance, but was subsequently found objectionable, on account of its rendering the wheels brittle, which led to the adoption of wrought-iron tires, by Mr. G. Stephenson, who was the first engineer that employed them; the wear of which is about $\frac{1}{12}$th of an inch per annum, or about $\frac{1}{3}$rd those of cast-iron: they are also generally formed of a slightly conical shape, with flanches on the inside, thus:—(*See Cut above.*)

Mr. George Stephenson's Patent Wheels.

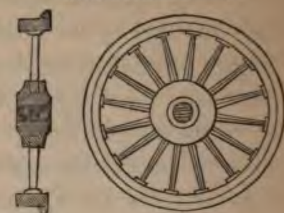


Section. Elevation.

The annexed cut represents Mr. George Stephenson's patent wheels; the spokes are of wrought-iron, and are formed hollow, the nave and rim being cast on to them; the rim is then turned in a lathe, and a wrought-iron tire fixed on it.

Mr. Losh's patent wheels have acquired great repute. The whole is of wrought iron, except the nave.

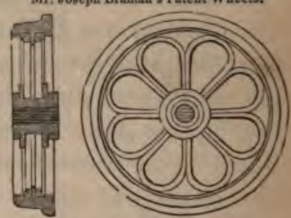
Mr. Losh's Patent Wheels.



Section. Elevation.

Mr. Joseph Bramah's are the last wheels produced, and certainly surpass all former wheels. The whole of this wheel is also formed of wrought-iron, except the nave, and it is finished by a wrought-iron ring being made hot, and contracted on to the spokes; the tire is put on in a similar manner, and further secured by bolts, and properly turned and finished.—*See Axle, Bearings and Curve.*

Mr. Joseph Bramah's Patent Wheels.



Section. Elevation.

WHIMS, large capstans connected with the shafts of mines, and worked by three or four horses.

WINCH, the name applied to the bent handle or crank, by which the axles of machines are turned when manual labour is employed in effecting it.

WINDLASS, a circular axis turned round by crank handles, by one or two men, for the purpose of raising water or minerals from wells or mines; the anchor used on board ships is raised by a windlass worked by shifting levers. The crank handle by which any contrivance is turned is also known by the name of a *windlass.*

WINDMILL, or WIND ENGINE, a contrivance for acquiring a first mover or power for machinery from the impulse of the wind, and which is adopted for various purposes. Windmills are most frequently employed in grinding corn; they were also much used formerly for draining marshy land, but steam power has superseded their use considerably, in common with other early machines..

Windmills are of two kinds, *vertical* and *horizontal.*

The vertical are those almost invariably met with, having four cross vanes or arms fixed at the extremity of an axis lying in a

horizontal position, or nearly so. The vanes are formed in the shape of trapeziums, of about 9 yards long, and 2 wide, and are covered with canvas or cloth upon open lattice-work framing. The position of the sails in this kind of windmill is obliged to be accommodated to the direction of the wind, and there are two modes of effecting it practised; viz., by the *post-mill*, which is built around and upon the trunk of a large tree, properly braced and strutted next the ground, and a certain height is settled for the lower and the upper floors, upon which it is turned bodily when required, a pivot or centre being formed in the upper floor, which rests upon the top part of the trunk; the lower flooring has a collar framed in it, which also rests upon the outer edge of the trunk, the latter being passed through the collar. The mill is turned by means of framing at the back, which descends in a sloping direction, and is fastened in a temporary manner to posts driven into the ground, or it is rested on the axle of a moveable wheel, which describes a circle round the mill, and thereby takes any position that may be necessary. The other method of setting the sails to the wind is accomplished by means of *smock-mills*, and which are built in a more substantial manner, the lower part being formed of stone or brickwork, and the upper of wood, usually in a conical form. The head is constructed on a moveable plan, and accommodates itself to the direction of the wind by means of some small sails situated at the back part of it.

Horizontal windmills are worked by sails set horizontally, the axis being in a perpendicular position. It is natural to suppose that the action of the wind would be much greater when employed in a direct manner against the sails, as in this case, than when acting in a lateral course, as it does with the former description, but the resistance presented by the vanes or sails upon returning against the wind, forms a great objection to their use; they are calculated at not above $\frac{1}{3}$rd to $\frac{1}{4}$th the power of the vertical.

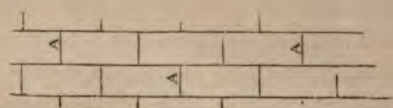
Mr. Robert Beatson's Patent Horizontal Windmill.

Mr. Robert Beatson effected a consider-

able improvement in them by his patent of 1798—he proposed having the vanes formed of suspended flaps, which were shut by the action of the wind, and upon returning they opened, allowing it to pass between them.

Both in the case of windmills and water-wheels, for grinding flour, the prime mover is connected with large mill-stones, between which the corn is ground, the motion being communicated to them from the sails by means of a vertical axle.

WINZE (in mining), a small pit or shaft sunk from one level to another, for the purpose of ventilation. Winzes are generally constructed in mines at regular distances, those of one level being placed midway between those of the level above or below it, thus:—



A, A, A, represent the winzes.

WOOD SCREW, an iron screw, in which the body tapers, but not the worm, the latter continuing straight to the extremity.

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